Available online at www.sciencedirect.com
ScienceDirect
PALAEO
Palaeogeography, Palaeoclimatology, Palaeoecology 253 (2007) 56–90
www.elsevier.com/locate/palaeo

Palaeoclimatic evolution and vegetational changes during the Late Oligocene–Miocene period in Western and Central Anatolia (Turkey)

Funda Akgün *, Mine Sezgül Kayseri [1], Mehmet Serkan Akkiraz [2]

Department of the Geological Engineering, Dokuz Eylül University, 35100 Bornova-İzmir, Turkey

Received 22 December 2004; received in revised form 26 February 2007; accepted 5 March 2007

Abstract

Neogene basins are widespread in Turkey and contain important lignite deposits. In this study, we reconstruct quantitatively the Late Oligocene–Miocene climate evolution in western and central Anatolia by applying the Coexistence Approach to the palynofloras obtained from the published literatures and ongoing studies.

The Coexistence Approach results show that sedimentation occurred mainly under warm subtropical climatic conditions during the Chattian and Aquitanian period in western Anatolia (16.5–21.3 °C mean annual temperature (MAT) and 5.5–13.3 °C mean temperature of coldest month (CMT)). Rare occurrences of dinoflagellate cysts in the Chattian and Aquitanian indicates a marine influence. After the regression of the sea during the Burdigalian period, climate becomes cooler due to a decrease of the Palaeotropical/Arctotertiary-ratio during the latest Burdigalian–Langhian. Vegetation developed under terrestrial conditions, which had started in the Burdigalian time in western and central Anatolia and continued to the early–middle Serravallian period. The climate was subtropical in western and central Anatolia during the early–late Serravalian (17.2 to 20.8 °C for MAT and 9.6 to 13.1 °C for CMT). Besides, increase of the CMT and MAT values in western and central Anatolia supports the latest Chattian–earliest Aquitanian warming and Middle Miocene climatic optimum being also globally observed. Warm temperate climatic conditions are observed in the Late Miocene. During the early–middle Tortonian, the values are 15.6 to 20.8 °C for the MAT, 5.5 to 13.3 °C for the CMT and 823 and 1520 mm for the mean annual precipitation (MAP). They had experienced dry seasons due to lower boundary of MAP lying at 823 mm during the middle–late Tortonian.

The palaeotopography of central Anatolia was higher, compared to that of western Anatolia during the Middle–Late Miocene as indicated by a rich species diversification in mountain forests. This study provides the first quantitative model for Late Oligocene–Miocene palaeoclimatic evolution in western and central Anatolia.

Keywords: Palaeoclimate; Palaeovegetation; Palynoflora; Coexistence Approach; Turkey

1. Introduction

Oligo–Miocene deposits outcrop over wide areas of western and central Anatolia (Fig. 1). In the west, the N–S trending Tertiary basins can mainly be classified as Kale–Tavas, Yatağan, Soma, Gördes, Bigadiç and Büyük Menderes region (e.g. Şengör and Yılmaz, 1981; Seyitoğlu and Scott, 1991; Akgün and Akyol, 1999; Yılmaz et al.,

* Corresponding author. Tel.: +90 232 4127308; fax: +90 232 4531129.
E-mail addresses: funda.akgun@deu.edu.tr (F. Akgün), sezgul.kayseri@ogr.deu.edu.tr (M.S. Kayseri), serkan.akkiraz@deu.edu.tr (M.S. Akkiraz).
[1] Tel.: +90 232 4127373.
[2] Tel.: +90 232 4127350.

0031-0182/$ - see front matter © 2007 Published by Elsevier B.V.
doi:10.1016/j.palaeo.2007.03.034

2000; Gürer and Yılmaz, 2002). In central Anatolia, Çankırı and Sivas basins were filled with marine and coal-bearing continental sediments (Erdoğan et al., 1996; Poisson et al., 1996; Akgün et al., 2002). These basins were dated by means of marine fossils, pollen, mammal and radiometric data (e.g. Atalay, 1980; Seyitoğlu and Scott, 1991; Akgün and Akyol, 1999; Akgün et al., 2000; Akgün and Sözbilir, 2001; Kaymakçı et al., 2001; Helvacı et al., 2004) (Table 1).

In this study, we concentrate on pollen and spore based palaeoclimatic reconstruction in order to obtain quantitative data about the Late Oligocene and Miocene climate evolution in both western and central Anatolia with the help of the Coexistence Approach (Mosbrugger, 1995; Mosbrugger and Utescher, 1997) For this purpose, in western Anatolia, pollen data were obtained from the Kale–Tavas, Soma, Gördes and Bigadiç basins and Büyük Menderes region by Akgün et al. (1986), Akgün and Akyol (1987), Akyol and Akgün (1990), Akgün and Akyol (1999) and Akgün and Sözbilir (2001). Additionally, the leaf flora from the Soma basin analyzed by Nebert (1978) and Gemici et al. (1991) have also been re-evaluated here to test the climatic results. In central Anatolia, palynological data were obtained from the Çankırı and Sivas basins and Konya–Ilgın, Ankara–Beypazarı and Kırşehir areas by Kayseri (2002), Kayseri and Akgün (2002), Akgün et al. (2000), Akgün et al. (1995), Karayiğit et al. (1999), Akgün et al. (2002). Moreover, we have also analyzed the palynological results of ongoing studies on Muğla–Yatağan and Burdur–Kavak in western Anatolia and Ankara–Beypazarı, Sivas–Vasıltepe, Karagöl and Akalın, Samsun–Havza and Elazığ areas in central Anatolia. We have summarized the present knowledge of the Oligocene–Miocene vegetation and palaeogeography in western and central Anatolia.

2. Stratigraphy

According to the most recent studies, the present day tectonic frame of Anatolia began to form in the Early Miocene (e.g. Şengör et al., 1985; Yılmaz, 1992). The palaeogeography of Turkey was dominated by an erosional highland area with continental deposition surrounded by shallow seas in the north, east and south at that time. This highland was dissected in the Aegean region by fault–bounded basins which have been generally N–S trending. In western Anatolia, the Kale–Tavas, Yatağan, Soma, Gördes, Bigadiç basins and several basins in Büyük Menderes region, were filled during the Late Oligocene and Miocene period.

Central Anatolia is made up of several continent fragments that were assembled during the Late Cretaceous–Early Tertiary time interval as a result of the closure of multibranched Neotethyan ocean (Şengör and Yılmaz, 1981). Sedimentary basins were also developed during the Cretaceous–Tertiary period in a variety of localities in central Anatolia. Complex deformations along the İzmir–Ankara–Erzincan collisional zone are partly recorded in the sedimentary successions of remnant basins evolved along the suture zone (Cater et al., 1991; Yılmaz, 1994; Koçyiğit et al., 1995; Erdoğan et al., 1996; Poisson et al., 1996; Yılmaz et al., 1997) (Fig. 1). The Çankırı and Sivas basins, situated on this complex collisional zone in central Anatolia were developed (Fig. 1).

The stratigraphical and lithological properties of the Tertiary basins outcropping in both western and central Anatolia are briefly described below.

2.1. Western Anatolia

2.1.1. The Kale–Tavas Basin

The Kale–Tavas basin is the oldest basin of western Anatolia, and its sedimentary sequence ranges from the Upper Oligocene to Lower Miocene (Fig. 1). The lowermost unit is a red thick, massive, poorly bedded and sorted coarse conglomerate. The conglomerate is dominantly made up of ophiolitic material derived from the underlying ophiolites. The grain size decreases towards the north, where red clastics pass laterally and vertically into grey conglomerates, which in turn give way to grey and well sorted sandstones with some limestone lenses (Yılmaz et al., 2000; Gürer and Yılmaz, 2002). In some places, they pass laterally into grey shales containing lignite beds. These are lagoonal and shallow marine clastics which contain palynomorphs, gastropods, bivalves and benthic foraminifers of the Late Oligocene to Early Miocene age (Gökçen, 1982; Hakyemez and Örçen, 1982; Koçyiğit, 1984; Hakyemez, 1989; Yılmaz et al., 2000; Akgün and Sözbilir, 2001; Gürer and Yılmaz, 2002). The Late Oligocene–Early Miocene palynological assemblages have been recorded from the Denizli–Kale, Tavas, Denizli–Kurbalık and Burdur–Kavak areas of the Kale–Tavas basin (Akgün and Sözbilir, 2001; Akgün et al., 2004).

2.1.2. The Yatağan Basin

In the Yatağan Basin, the Middle Miocene succession unconformably overlies metamorphic rocks (Fig. 1). It generally consists of conglomerate, sandstone, claystone, limestone, tuffite and contains numerous coal seams at different levels. The Middle Miocene age was obtained from the mammals and palynological data (Atalay, 1980; Erdei et al., 2002). A brown to red colored continental sequence unconformably overlies the Middle Miocene succession and is made up of conglomerate and sandstone alternations (Fig. 1). Upper Miocene red beds include a rich mammal fauna (Atalay, 1980).

2.1.3. The Büyük Menderes region

The N–S trending Neogene basins are located both in the northern and southern part of Büyük Menderes River. The Neogene sedimentary succession rests unconformably on metamorphic rocks and is generally made up of conglomerate, sandstone, mudstone and clayey limestone in lacustrine and fluviatile facies (Fig. 1). The coal formations are observed throughout the sedimentary sequence at different levels. Akgün and Akyol (1999) undertook detailed palynological studies in Aydın–İncirliova, Köşk, Başçayır, Sarayköy and Hasköy areas in the northern part and in Aydın–Söke, Şahinali and Kuloğulları areas in the southern part of the Büyük Menderes River (Fig. 1). The age of sediments outcropping in the Büyük Menderes region was considered to be of the latest Early Miocene–earliest Late Miocene on the basis of palynological data (Akgün and Akyol, 1999).

2.1.4. The Soma Basin

The sediments of the Soma basin are preserved in a small intramontane setting. The sequence of the region unconformably overlies the Early Cenozoic and older siliciclastic and carbonate rocks of the ophiolities (Fig. 1). The sediments of this basin are considered to have been formed mainly on the NE–trending karstic and possibly fault–bounded topographic depressions and synclinal troughs. The sedimentary fill of the region consists of coarse and fine–grained detrital rocks, marls, limestones and volcanic rocks (Fig. 1). According to İnci (2002), the Miocene non-marine sedimentary sequence of the Soma coalfield contains lower, middle and upper coal successions. The marls, which are situated over the first coal succession, contain plant remains including leaves. Palynological subdivisions and some radiometric age correlations from the lignite–bearing Neogene sequences indicate an Early to Late Miocene age (e.g. Nebert, 1978; Gemici et al., 1991; Seyitoğlu and Scott, 1991; Takahashi and Jux, 1991; İnci, 2002). The palynological data has been obtained from Akgün (1993), Akgün et al. (1986) and Gemici et al. (1991). Additionally, the leaf flora has also been acquired from Nebert (1978) and Gemici et al. (1991).

2.1.5. The Gördes Basin

The Gördes basin is located on the eastern side of the Soma basin (Fig. 1). Detailed stratigraphic and palaeontological studies were made in the Gördes basin by various authors (e.g. Nebert, 1961; Yağmurlu, 1984; Akgün and Akyol, 1987; Seyitoğlu and Scott, 1994). The stratigraphic sequence of the Gördes basin rests unconformably on the ophiolites (Fig. 1). The alluvial fan deposits including conglomerates and sandstones occur in the lower part of the succession. The age of the succession is the Early Miocene (Yağmurlu, 1984). The Middle Miocene fluviatile sediments unconformably overlie the Early Miocene sediments and consist of sandstone, conglomerates and coal–bearing claystone alternation. The sequence continues with lacustrine sediments that are cut by lavas and unconformably overlain by tuffs. The radiometric and palynological data suggest that the age of the Gördes basin is Early–Middle Miocene (Yağmurlu, 1984; Akgün and Akyol, 1987; Seyitoğlu and Scott, 1994). The palynological results were obtained from the Akhisar–Çıtak area of the Gördes basin by Yağmurlu (1984) and Akgün and Akyol (1987) (Fig. 1).

2.1.6. The Bigadiç Basin

The Neogene volcano–sedimentary rocks in ascending order are as follows: basal volcanic, lower limestone, a lower tuff unit, a lower borate zone including coal lenses, an upper tuff unit, an upper borate zone and olivine basalt (Helvacı, 1995; Helvacı et al., 2004) (Fig. 1).

The palynological content of the lower and upper borate zones indicates that the age of the Bigadiç basin is the Middle Miocene–earliest Late Miocene (Akyol and Akgün, 1990). However, the age of the Bigadiç basin is still a matter of debate. Recent studies of Helvacı (1995) and Helvacı et al. (2004) show that the age of the Bigadiç basin is late Burdigalian on the basis of K/Ar analysis. The sporomorph assemblage is quite similar to that of latest Burdigalian assemblage of the Samsun–Havza area (Kayseri, 2002; Kayseri and Akgün, 2002). For this reason, the age of the Bigadiç basin has been interpreted as the latest Burdigalian.

2.2. Central Anatolia

In this area, the geological properties of the Sivas and Çankırı basins are briefly described. In addition, the geology of the Konya–Ilgın, Ankara–Beypazarı and Kırşehir areas has also been defined.

2.2.1. The Sivas Basin

The sedimentary succession in the Sivas basin unconformably overlies the pre–Miocene clastic rocks and generally consists of sandstone, mudstone, limestone and lignite intercalations (Özdemir, 2000). Basalt, gypsum and interbedded limestone become dominant towards the upper part of the succession. Radiometric

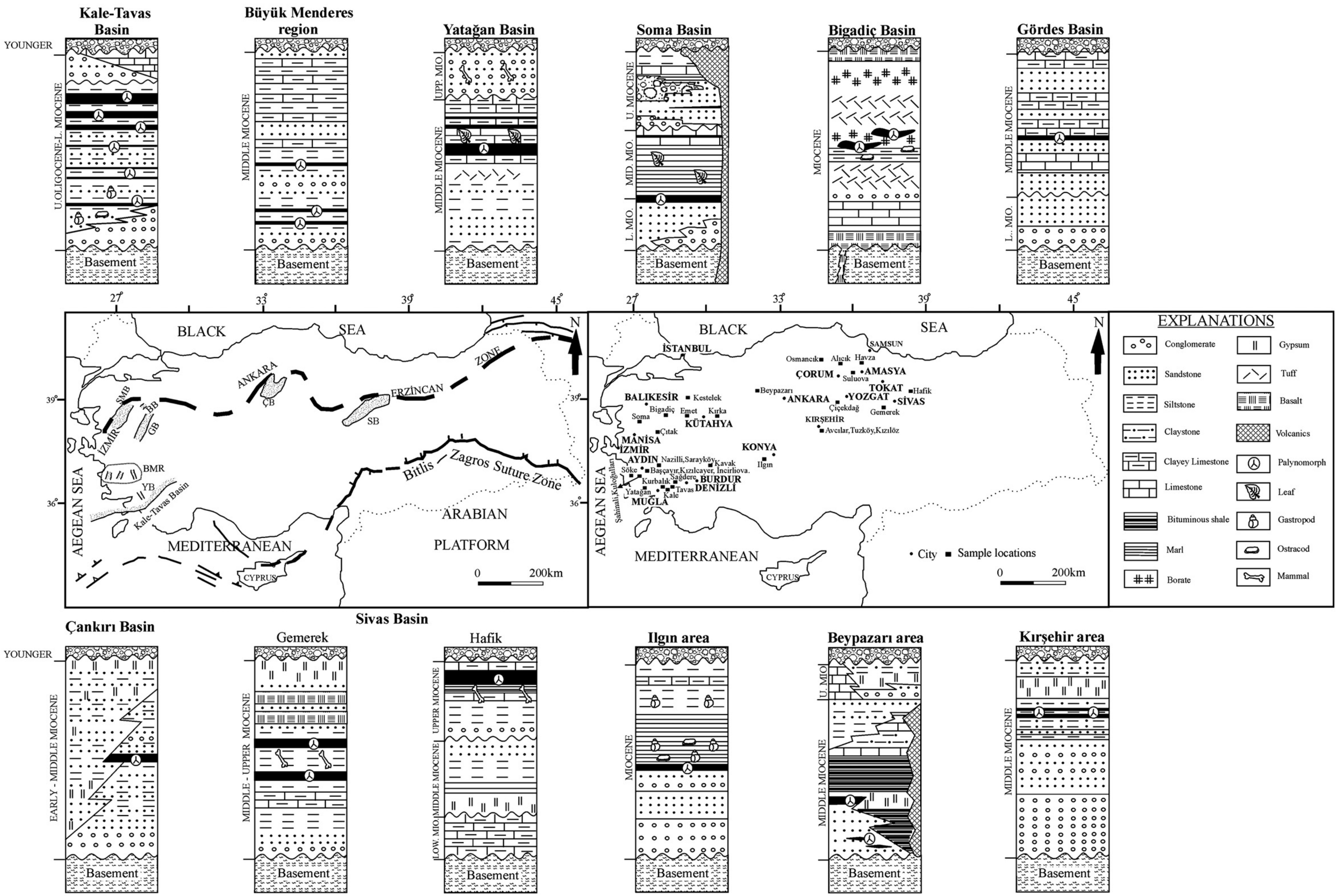


Fig. 1. Map of Anatolia and its surroundings showing localities of the Neogene basins. Schematic stratigraphic sections for the basins and areas were prepared with data from Yılmaz et al. (2000) (for the Kale–Tavas basin); Atalay (1980) (for the Yatağan Basin (YB)); Akgün and Akyol (1999) (for the Büyük Menderes region (BMR)); İnci (1998) (for the Soma Basin (SMB)); Yağmurlu (1984) (for the Gördes Basin (GB)); Helvacı (1995) (for the Bigadiç Basin (BB)); Erdoğan et al. (1996) (for the Çankırı Basin (ÇB)); Özdemir (2000) and Akgün et al. (2000); (for the Sivas Basin (SB) of Gemerek and Hafik areas respectively); Yağmurlu et al. (1988) (for the Beypazarı area); Karayiğit et al. (1999) (for the Ilgın area); Akgün et al. (1995) (for the Kırşehir area).

Table 1
Available age data on the basis of terrestrial, shallow marine fossils and radiometric data

Location		Age	Samples	Defined taxa	Number of taxa used in CA	Sources for dating	References
Western Anatolia	Aydın–Hasköy, Köşk, Sarayköy Muğla–Sekköy, Turgut	Latest Serravallian–earliest Tortonian	13	49	23	Spores and pollen Mammals, Spores and pollen	Akgün and Akyol (1999) Atalay (1980) Erdei et al. (2002)
	Aydın–Söke, Şahinali,İncirliova, Köşk, Hasköy	Early–middle Serravallian	156	49	27	Spores and pollen	Akgün and Akyol (1999)
	Muğla–Yatağan					Mammal, spores and pollen	(Atalay, 1980; Erdei et al., 2002)
	Akhisar–Çıtak					Spores and pollen	(Yağmurlu, 1984; Akgün and Akyol, 1987)
	Manisa–Soma					Spores and pollen	(Akgün, 1993; Akgün et al., 1986)
	Aydın–Kuloğulları, Başçayır	Langhian	15	36	28	Spores and pollen	Akgün and Akyol (1999)
	Balıkesir–Bigadiç, Emet, Kırka and Kestelek	Latest Burdigalian	60	26	21	Spores and pollen K/Ar analysis	Akyol and Akgün (1990) (Helvacı, 1995; Helvacı et al., 2004)
	Denizli–Kurbalık	Early Aquitanian	20	28	24	Spores and pollen benthic foraminifers	Akgün and Sözbilir (2001)
Central Anatolia	Burdur–Kavak	Earliest Aquitanian	4	27	24	Spores and pollen benthic foraminifers	Akgün et al. (2004)
	Denizli–Kale, Tavas	Latest Chattian	172	29	21	Spores, pollen, dinoflagellates and benthic foraminifers	Akgün and Sözbilir (2001)
	Sivas–Hafik	Middle Tortonian	4	27	20	Mammals, spores and pollen	Akgün et al. (2000)
	Elazığ	Early Tortonian	2	19	10	Spores and pollen	
	Sivas–Vasıltepe	Latest Serravallian–earliest Tortonian	3	37	20	Spores and pollen Ar/Ar analysis	(Kayseri, 2002; Kayseri and Akgün, 2002; Langereis et al., 1990)
	Kırşehir–Tuzköy					Spores and pollen	Akgün et al. (1995)
	Sivas–Karagöl, Akalın Amasya–Alıcık Çorum–Evlik, Ayva, İskilip, Zambal,İkizler, Kumbaba , Dodurga, İncesu	Early–middle Serravallian	110	62	30	Spores and pollen	(Kayseri, 2002; Kayseri and Akgün, 2002)
	Konya–Iligin					Spores and pollen	Karayiğit et al. (1999)
	Kırşehir–Avcıköy, Hacıbektaş					Spores and pollen	Akgün et al. (1995)
	Yozgat–Çiçekdağ					Spores and pollen	Akgün et al. (2002)
	Ankara–Beypazarı					Rodent fauna spores and pollen	(Bruijn and Saraç, 1991, 1992; Yağmurlu et al., 1988)
	Samsun–Havza	Latest Burdigalian	2	40	29	Spores and pollen	(Kayseri, 2002; Kayseri and Akgün, 2002)

Table also shows the defined taxa and number of taxa used in the CA.

data, mammals, micromammals and palynological data suggest a Middle–Late Miocene age for the succession (Sümengen et al., 1990; Langereis et al., 1990; Kayseri, 2002; Kayseri and Akgün, 2002) (Fig. 1).

In the Hafik region, the Late Miocene succession including a clastic sequence with a lignite horizon was recognized by Yılmaz (1983). This succession rests unconformably on pre-Upper Miocene sediments and comprises coarse clastics with gypsum in the lower part and carbonate-rich clastics in the upper part. A lignite horizon occurs in the upper part of the succession (Yılmaz, 1983). Akgün et al. (2000) studied the palynology of the Sivas–Hafik area and suggested a Late Miocene age based on the mammal (MN11-MN12) and palynological data.

2.2.2. The Çankırı Basin

Along the northern border of the Çankırı basin, the sedimentary fill surrounding the Çorum area includes horizontal continental sequences of Miocene age and rests unconformably on older units (Fig. 1). In the Miocene, red and grey conglomerates, sandstones, shales and gypsum horizons occur in the lower part. The conglomerates are in fluvial facies and include several gypsum horizons. Stratigraphically, towards the upper parts of the Miocene succession, red to green shales with laminated gypsum beds become dominant. Radiometric and mammal data indicate an Early–Middle Miocene age (Şen et al., 1998; Kaymakçı et al., 2001). Palynological studies were undertaken in the, Alıcık, Ayva, Dodurga, Evlik, İkizler, İncesu, İskilip, Kumbaba, Zambal, Akalın, Çiçekdağ, Sivas–Karagöl and Samsun–Havza areas by Kayseri (2002) and Kayseri and Akgün (2002).

2.2.3. The Ilgın area

The Konya–Ilgın lignite field consists mainly of fluvial and lacustrine sediments of Neogene age that were deposited unconformably over the basement rocks. The sedimentary succession starts with fluvial sediments and grades upward into marls and lignite including gastropods and ostracods (Fig. 1). Other lithologies comprise mudstone, clayey limestone and tuffite. Different ages have been proposed for the Ilgın lignites. Çağlar and Ayhan (1991) suggested a Late Miocene based on limited ostracod fauna and palynological data. However, Tunoglu and Celik (1995) have revised this to Early Miocene according to ostracod fauna. Finally a Middle Miocene age was suggested by Karayiğit et al. (1999) on the basis of palynological data.

2.2.4. The Beypazarı area

The Middle Miocene succession, which unconformably overlies the basement rocks of metamorphic origin, starts with fluviatile sediments including conglomerates, sandstone, mudstone and interfingering limestones (Fig. 1). The lower part of the Middle Miocene succession contains two lignite seams at different levels. Shales, bituminous shales and tuffs become dominant towards the middle part of the succession and conformably overlie the fluviatile sediments. Claystone, chert and silicified limestone levels occur over the bituminous shales. Moreover, the succession is cut by pyroclastic breccia, tuffs and basaltic lava flows. Claystones, mudstones and sandstones occur at the top of the Middle Miocene succession. The Late Miocene fluvial sediments conformably overlie the Middle Miocene succession (Yağmurlu et al., 1988). Yağmurlu et al. (1988) accepted the age of the Ankara–Beypazarı lignites as Middle Miocene on the basis of the palynological data. However, Early–Middle Miocene ages were suggested by Bruijn and Saraç (1991, 1992) on the basis of rodent faunas. The palynological data in the locality of Ankara–Beypazarı were obtained from Yağmurlu et al. (1988).

2.2.5. The Kırşehir area

Middle Miocene sediments crop out in the Hacıbektaş, Avcıköy and Tuzköy localities in the southern part of the Kırşehir area and rest unconformably on the pre–Miocene basement (Fig. 1). Sedimentation starts with massive conglomerate and grades into sandstones and siltstones to the top. Coal seams are observed in the upper part of the sequence (Fig. 1). Gypsum horizons, sandstones and claystones occur at the top of the sequence (Fig. 1). Akgün et al. (1995) studied the palynology of the Kırşehir area and suggested a Middle Miocene age. The younger sedimentary successions unconformably overlie the Middle Miocene succession.

3. Material and methods

In this study, all palynofloras were subjected to the Coexistence Approach (CA) proposed by Mosbrugger and Utescher (1997). Additionally, the megaflora obtained from the Soma basin by Nebert (1978) and Gemici et al. (1991) were also subjected to the CA. A total of 440 samples in western Anatolia and 121 samples in central Anatolia were used (Table 1). Moreover, 67 taxa in western Anatolia and 68 taxa in central Anatolia were defined and these defined taxa were applied to the CA (Table 1). The CA technique is based on the "nearest living relative philosophy" i.e. the assumption that climatic requirements of Tertiary plant taxa are similar to those of their NLRs. The aim of the CA is to find intervals of various climate parameters for a given fossil flora in which a maximal number of NLRs of this fossil flora can coexist; these coexistence intervals are considered the best description of the palaeoclimatic situation under which fossil flora lived (Mosbrugger and Utescher, 1997). In this method, it is understood that the real palaeoclimatic values are encompassed by this coexistence interval. The climatic parameters discussed here are mean annual temperature (MAT), mean temperature of coldest month (CMT), mean temperature of warmest month (WMT) and mean annual precipitation (MAP). The reliability of the obtained climatic data also varies depending on the climatic parameter considered; the resolution is the highest for the temperature related parameters (MAT, CMT, and WMT) where it generally is in the range of 1–2 °C. The CA is calculated on the basis of presence/absence rather than relative abundance (Mosbrugger and Utescher, 1997; Pross et al., 2001). As an additional climate proxy, we have determined the relative proportion of the palaeotropical (P) and arctotertiary (A) elements for all palynofloras. According to classical definitions (e.g. Mai, 1991; Planderová, 1991), the arctotertiary elements are used for plants which grew in the arctic area during the Paleogene under temperate to warm temperate climates and correspondingly occur today in the temperate zone (Ivanov et al., 2002). In contrast, palaeotropical elements are plants which have their present distribution primarily in the palaeotropic area i.e. in the tropical regions of Asia and Africa (Ivanov et al., 2002).

The use of multivariate analytical methods in palynological and palaeobotanical studies has become more widespread in the last twenty years (Spicer and Hill, 1979; Kovach, 1988, 1989). The choice of methods depends on the type of data and the specific problems being solved (Kovach, 1989). The unweighted pair group Average Linkage Cluster (UPGMA) and farthest neighbour cluster methods and detrended correspondence analysis have been chosen for this study in order to identify groups of palaeocommunity types and samples that are associations of the variables contained within the data available. For the cluster analysis, the proximity matrices for the correlation of the palaeocommunities have been produced with Modified Morisita and Percent similarities. To interpret the palaeovegetation, the statistical analyses were done using MVSP (version 3.1). Absolute percentages with respect to pollen sum (including all pollen and spores) were used for statistical treatment.

4. Vegetation analysis

According to previous studies, vegetational composition and characteristic features of western and central Anatolia during the Oligo–Miocene period were determined. (Akgün and Akyol, 1987; Gemici et al., 1991; Akgün et al., 1995; Akgün and Akyol, 1999; Karayiğit et al., 1999; Akgün and Sözbilir, 2001; Erdei et al., 2002; Kayseri, 2002; Kayseri and Akgün, 2002; Akgün et al., 2007). In this study, we provide information about changes in the ratio of palaeotropical over arctotertiary elements (P/A–ratio) which presumably reflects climatic and vegetational changes in the western and central Anatolia. In addition, to the reconstruction of the palaeovegetation of western and central Anatolia, the data chosen from previous and ongoing studies have been applied to cluster and detrended correspondence analysis.

4.1. The Chattian and Aquitanian

According to the palynological data, the Late Oligocene–Early Miocene consists of three stratigraphic stages which are the latest Chattian and the earliest and early Aquitanian obtained from the Kale–Tavas basin in western Anatolia (Akgün and Sözbilir, 2001). The palynomorph assemblage of the latest Chattian was defined from the Denizli–Kale area (Akgün and Sözbilir, 2001) (Fig. 1). Characteristic for the vegetation of that time is the abundance of swamp forest elements which are characterized by palaeotropical elements like *Calamus*, *Engelhardia*, Sapotaceae and Schizaceae. The abundance of palaeotropical elements shows that the P/A–ratio is represented by high percentage (Fig. 2). Correspondingly, arctotertiary elements of the mixed mesophytic vegetation such as *Ulmus*, *Alnus*, *Carya* and *Carpinus* are less abundant in the latest Chattian.

The UPGMA cluster analysis method has been applied to the reconstruction of the palaeovegetation of the latest Chattian in western Anatolia. The dendrogram of Fig. 3 shows three groups of samples (1–3) and also into three palaeocommunities (A–C). In the sample dendrogram, assemblage 1 comprises dominance by swamp and mixed mesophytic forest elements and low percentages of the mountain, riparian and freshwater elements. This assemblage includes dinoflagellate species of *Deflandrea* sp., *Spiniferites pseudofurcatus* (Sarjeant), *Polysphaeridium* sp. and *Areoligera* sp. (Akgün and Sözbilir, 2001). Assemblage 2 includes high percentages of swamp, mixed mesophytic, riparian and freshwater elements. Assemblage 3 constitutes dominance of riparian, mixed mesophytic, freshwater and swamp elements. The frequency of the mixed mesophytic, mountain and riparian elements in the assemblage 2 is greater than in assemblages1 and 3.

The earliest and early Aquitanian palynomorph assemblages have been determined from the samples of Burdur–Kavak and Denizli–Kurbalık areas in western

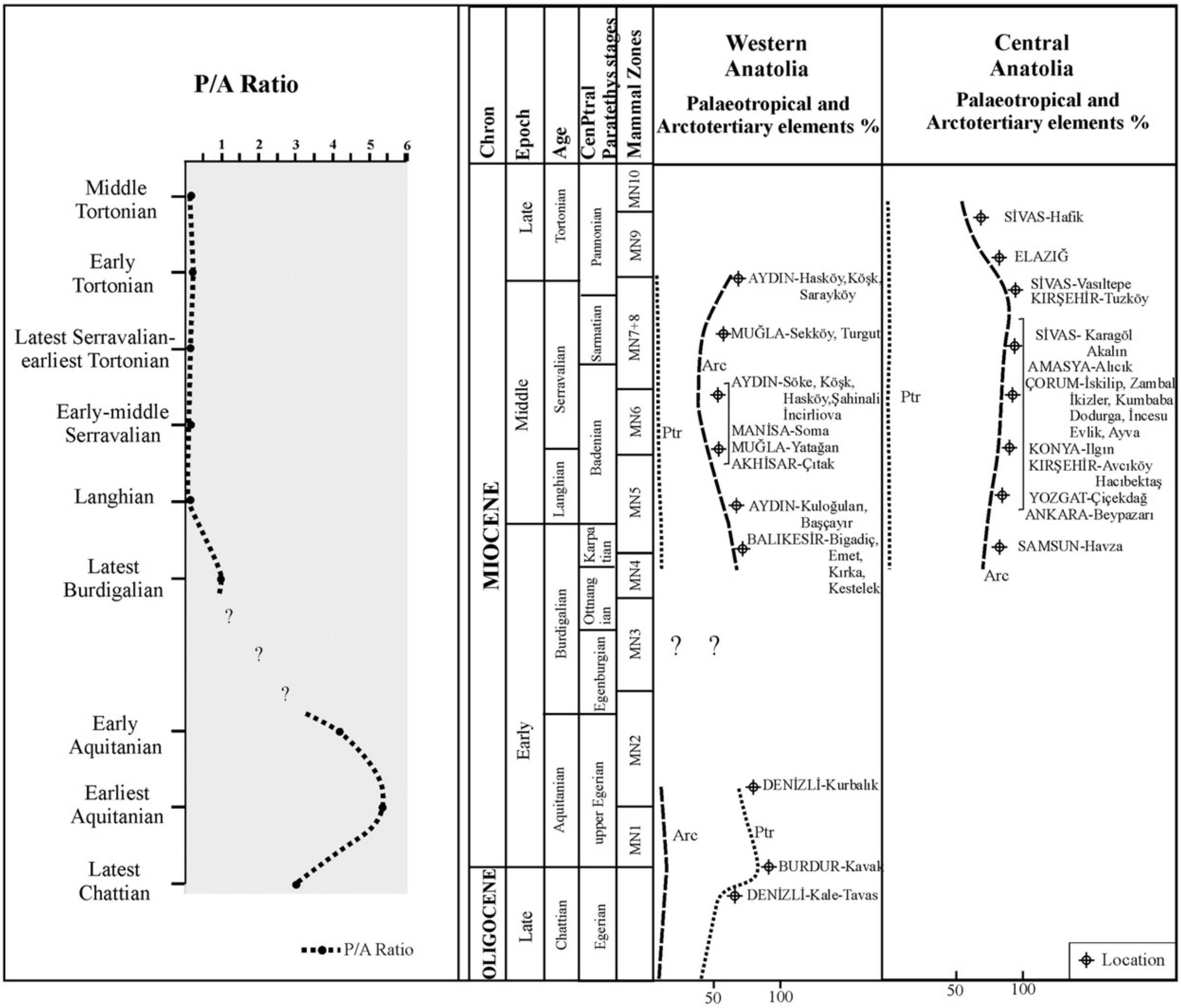


Fig. 2. The relative percentages of palaeotropical and arctotertiary elements derived from the samples of western and central Anatolia and changes of the P/A ratio in western and central Anatolia. The quantitative palynological data are based on absolute spore and pollen counts.

Anatolia (Akgün and Sözbilir, 2001; Akgün et al., 2004). Akgün et al. (2004) considers the palynomorph assemblage of Burdur–Kavak area to be the earliest Aquitanian. This assemblage includes predominant mixed mesophytic elements such as *Engelhardia, Castanea* and Cyrillaceae, which are characteristically palaeotropical. Arctotertiary elements of the mixed mesophytic forest (*Tilia* and *Carya*) are less abundant in the assemblage. The palynomorph assemblage from the Denizli–Kurbalık samples was defined as early Aquitanian (Akgün and Sözbilir, 2001). During this period, *Castanea*, species of *Quercus* type, *Ulmus* and *Carya* were dominant as arctotertiary elements of the mixed mesophytic forest. Moreover, Cyrillaceae, *Engelhardia* and Myricaceae, which are palaeotropical elements of the mixed mesophytic, swamp and riparian forests, are abundant in the early Aquitanian palynomorph assemblage. Palaeotropical elements in the earliest Aquitanian palynomorph assemblage are more abundant than in the early Aquitanian palynomorph assemblage. In addition, the species of dinoflagellate cyst are not observed in the late Aquitanian palynomorph assemblage and these species are found less frequently in the early Aquitanian palynomorph assemblage.

The dendrograms of Fig. 4 show two groups of samples (1 and 2) and three groups of palaeocommunities (A–C). In the sample dendrogram, assemblage 1 incorporates the earliest Aquitanian samples which are characterized by more abundant mixed mesophytic forest elements and low frequencies for dinoflagellate species, freshwater and riparian elements. Assemblage 2 is characterized by the late Aquitanian samples and consists

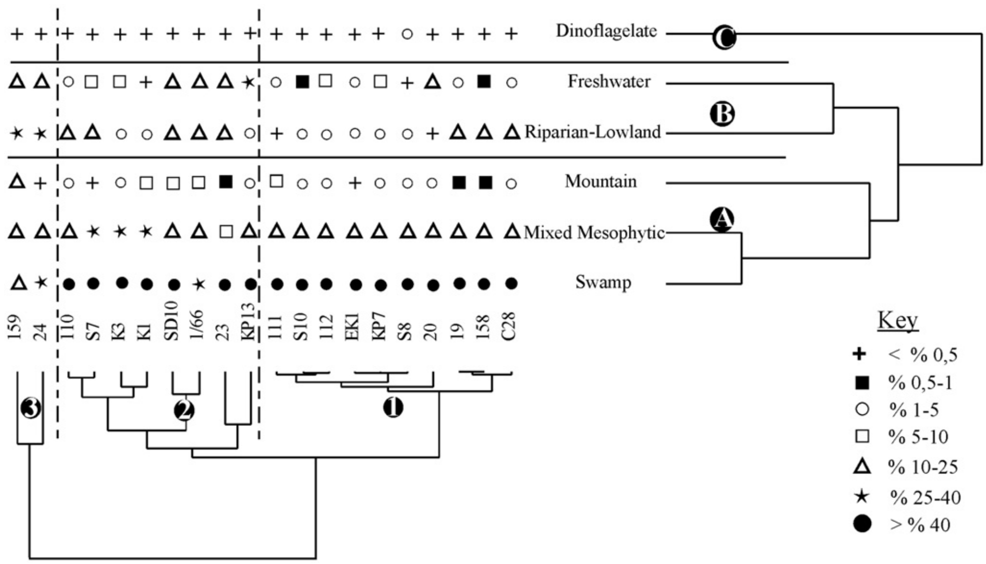


Fig. 3. Dendrograms of the latest Chattian for UPGMA cluster analysis of palaeocommunities (side) and samples (bottom), using Modified Morista's similarity.

predominantly of the mixed mesophytic and swamp forest elements. It also indicates the absence of dinoflagellate cysts and the low abundances of mountain and freshwater elements compared to assemblage 1.

Palaeotropical elements are observed in high percentages during the Chattian and Aquitanian (46–75%). However, maximum values of palaeotropical elements are achieved in the earliest Aquitanian (75%) (Fig. 2). By contrast, arctotertiary elements have low percentages in this period (12–14%). The presence and variations in percentages of palaeotropical elements indicate that the Chattian was cooler than the earliest Aquitanian (Fig. 2). During the climatic change from the earliest to early Aquitanian, a degree of cooling is observed but this temperature decrease is not as much as in the Chattian. Swamp forest elements such as Taxodiaceae, *Nyssa* and

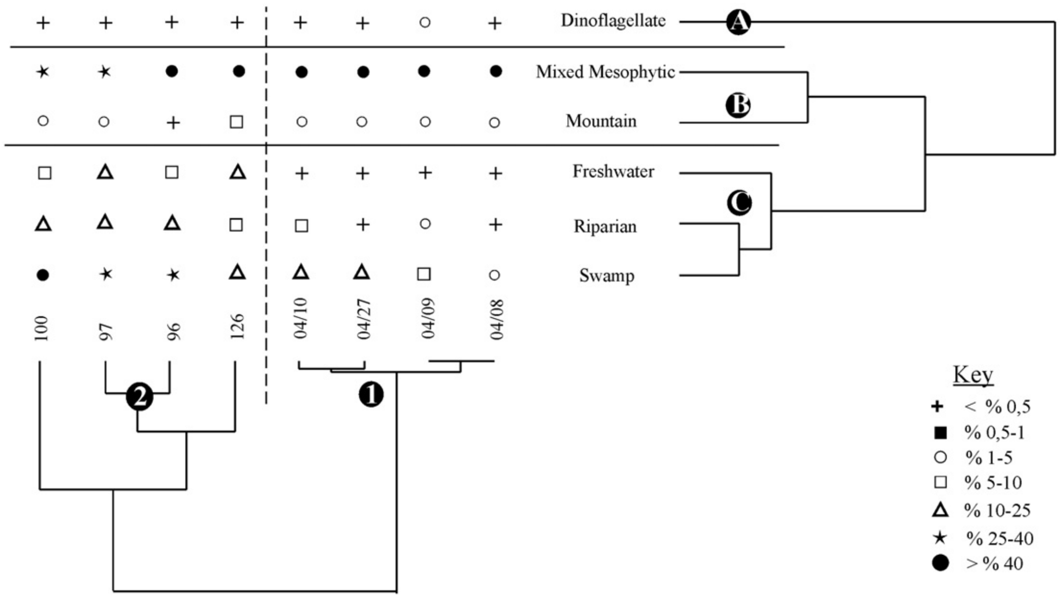


Fig. 4. Dendrograms of the earliest and early Aquitanian for UPGMA cluster analysis of palaeocommunities (side) and samples (bottom), using Modified Morista's similarity.

Myricaceae are dominant in the latest Chattian and also in the early Aquitanian. The samples of the earliest Aquitanian defined in the Burdur–Kavak area include predominantly mixed mesophytic forest elements such as *Carya*, Cycadaceae, *Engelhardia*, *Tilia* and *Quercus*.

4.2. The latest Burdigalian

The latest Burdigalian palynomorph assemblage has been recorded from the Samsun–Havza area of the Çankırı basin in central Anatolia and from the Balıkesir–Bigadiç, Emet, Kırka and Kestelek areas of the Bigadiç basin in western Anatolia (Akyol and Akgün, 1990; Kayseri and Akgün, 2002) (Fig. 1). Swamp, riparian and mixed mesophytic forest elements in the samples of Samsun–Havza and Balıkesir–Bigadiç, Emet, Kırka and Kestelek areas consist of Schizaceae, Cyrillaceae, Myrtaceae, Myricaceae, *Castanea* and *Engelhardia*, which are characterized by palaeotropical elements. The mountain forest species of arctotertiary elements (*Cathaya* and *Pinus haploxylon* type) are in high percentages in the assemblage of these areas. Therefore, the P/A–ratio is low and it shows cooling during the latest Burdigalian in western and central Anatolia (Fig. 2).

The Bigadiç basin is different from the other Neogene basins of western and central Anatolia because the sedimentary sequence included borates. The borate deposits in the Bigadiç basin occur in carbonate rich facies being suggestive of a period of high evaporation and salinity and low alkaline perennial lake levels (Helvacı, 1995). It is observed in the samples of borate bearing sediments that the herb species were very abundant and especially the species of Chenopodiaceae reached high percentages while the mixed mesophytic, riparian and swamp forest elements were less abundant. According to Helvacı (1995), partial desiccation recurred several times and geochemical springs were observed in association with borate deposits in the Bigadiç basin. It is observed that the species of Chenopodiaceae were more abundant in the samples with borate. Hence, it can be said that the geochemical springs and the recurring evaporatic phases in this region can be the reason for this abundance of Chenopodiaceae.

4.3. The Langhian

The Langhian palynomorph assemblage is defined from the samples of Aydın–Kuloğulları and Başçayır localities of Büyük Menderes region in western Anatolia (Akgün and Akyol, 1999) (Fig. 1). The Aydın–Başçayır samples were collected from the northern part of the Büyük Menderes region by the authors. The swamp forest elements such as Taxodiaceae and Myricaceae are predominant in the samples of the Aydın–Başçayır area. In addition, the content of these samples is also characterized by the abundance of the mixed mesophytic and mountain forest elements (*Pinus haploxylon* type and species of the *Quercus* type). The Aydın–Kuloğulları samples were collected from the southern part of the Büyük Menderes region. The riparian forest elements *Alnus* and Simaroubaceae are more abundant in the Aydın–Kuloğulları samples and the mountain and mixed mesophytic forests elements are predominant in the assemblage. Open vegetation species such as Compositae, Chenopodiaceae and Poaceae are observed in low frequency and percentage; these forms accompany riparian, mountain and mixed mesophytic forests.

The percentages of palaeotropical and arctotertiary elements in the latest Burdigalian decrease and this reduction continued through the Langhian period. The percentage of subtropical elements, which are characterized by species of Sapotaceae, *Engelhardia* and Symplocaceae, started to increase in the latest Burdigalian.

In the palaeocommunities dendrogram, assemblage A is dominated by swamp forest and low percentages of herb species such as Chenopodiaceae, Umbelliferae and Poaceae (Fig. 5). Assemblage B includes high percentages of riparian and mixed mesophytic forest elements and low frequencies of the freshwater elements. Assemblage C is dominated by mountain and mixed mesophytic forest elements (Fig. 5).

4.4. The early and middle Serravallian

The early and middle Serravallian palynomorph assemblages were determined from Aydın–İncirliova, Hasköy, Köşk, Şahinali and Söke areas in the Büyük Menderes region (Akgün and Akyol, 1999), Soma (Gemici et al., 1991), Gördes (Akgün and Akyol, 1987) and Yatağan basins (Erdei et al., 2002) in the west, the Çankırı basin (Kayseri, 2002; Kayseri and Akgün, 2002), Kırşehir–Avcıköy and Hacıbektaş, Ankara–Beypazarı and Konya–Ilgın areas (Akgün et al., 1995; Karayiğit et al., 1999) in the east respectively (Fig. 1).

In western Anatolia, mixed mesophytic (*Quercus*, *Castanea*, *Ulmus*, *Engelhardia* and Cyrillaceae) and swamp (Myricaceae, *Nyssa* and Taxodiaceae) forests were well developed during the early and middle Serravallian. The riparian forest element *Alnus* is abundant in these sporomorph assemblages of western Anatolia and it dominantly occurs in the sporomorph assemblages of the Aydın–Hasköy and Köşk samples. The mountain forest elements have low percentages and high frequency in all samples of the early and middle

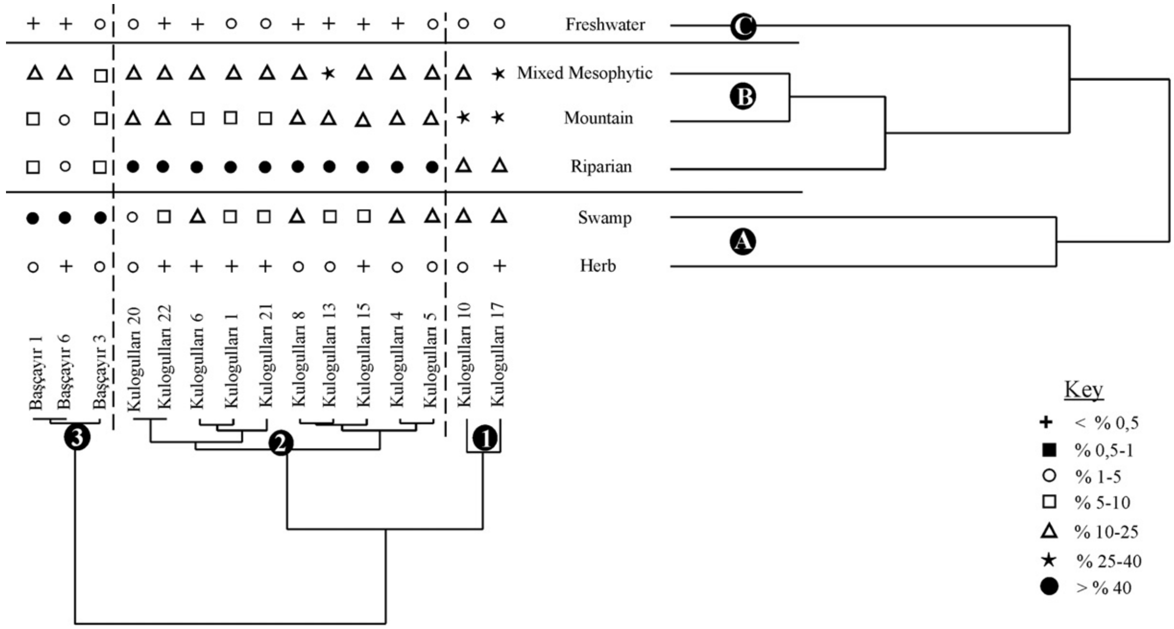


Fig. 5. Dendrograms of the Langhian for UPGMA cluster analysis of palaeocommunities (side) and samples (bottom), using Modified Morista's similarity.

Serravallian. However, only in the samples of Aydın–İncirliova, the mountain forest elements achieve high percentages, characterized mainly by *Pinus haploxylon* type. The subtropical elements of the mixed mesophytic, swamp and riparian forest elements are observed more abundantly in western and central Anatolia. In contrast to western Anatolia, mountain forest elements more abundantly accompany the subtropical forest community in central Anatolia. Species of open and freshwater vegetations such as Poaceae, Chenopodiaceae and Nymphaceae are frequently observed and in low percentages in the sporomorph assemblage of the middle Serravallian (like the Langhian samples).

To reconstruct the palaeovegetation, detrended correspondence analysis has been applied to the samples of the middle–late Serravallian in western and central Anatolia (Figs. 6 and 7). Both samples and palaeocommunities have been plotted. The attraction domain for western Anatolia is situated in the right of the plot and characterized by dominance of the swamp, mixed

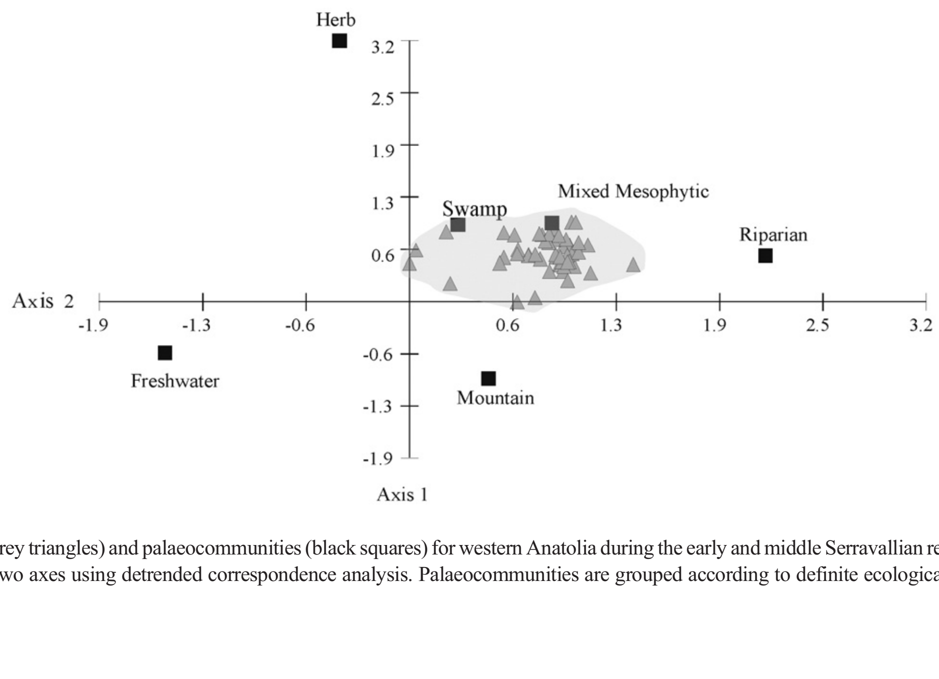


Fig. 6. Samples (grey triangles) and palaeocommunities (black squares) for western Anatolia during the early and middle Serravallian represented by in the space of the first two axes using detrended correspondence analysis. Palaeocommunities are grouped according to definite ecological markers of taxa.

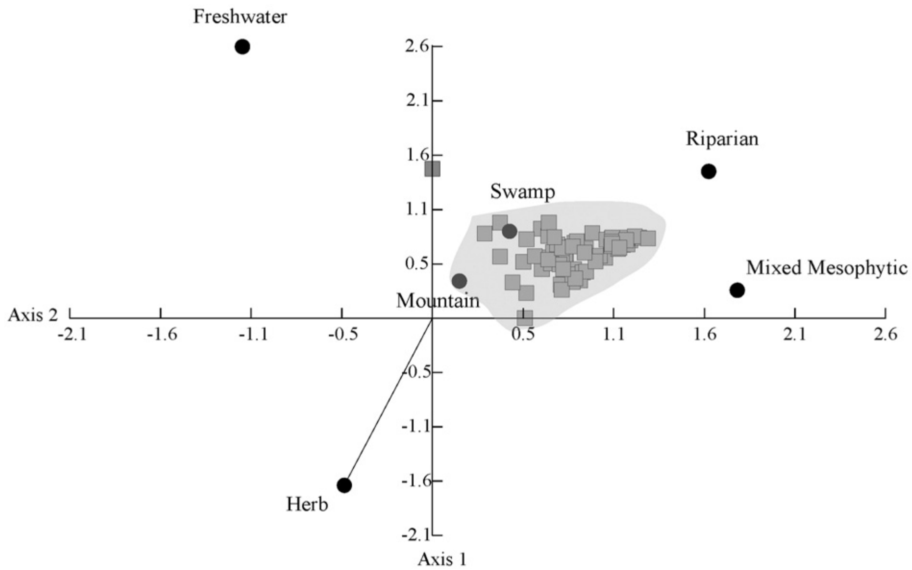


Fig. 7. Samples (grey squares) and palaeocommunities (black dots) for central Anatolia during the early and middle Serravallian represented by in the space of the first two axes using detrended correspondence analysis.

mesophytic and riparian elements. The attraction domain for central Anatolia is also located to the right side of plot and is represented by the predominance of mountain, swamp, riparian and mixed mesophytic palaeocommunities. Central Anatolia should have had a higher palaeotopography than western Anatolia according to presence of mountain elements such as *Pinus haploxylon* and *silvestris* types, *Abies*, *Picea*, *Cathaya* and *Podacarpus* in central Anatolia.

The percentages of arctotertiary and palaeotropical elements decrease from the early Serravallian to the middle Serravallian. The percentages of subtropical elements also reach maximum values in western and central Anatolia. However, it is observed that the percentage of subtropical species such as Oleaceae, *Podacarpus* and Cyrillaceae in central Anatolia is much more than in western Anatolia.

4.5. The latest Serravallian–earliest Tortonian

The latest Serravallian–earliest Tortonian palynomorph assemblages were defined from the Aydın–Köşk, Hasköy, Sarayköy areas of the Büyük Menderes region (Akgün and Akyol, 1999), Yatağan basin (Muğla-Sekköy and Turgut) in western Anatolia and Sivas basin (Sivas–Vasıltepe) (Kayseri and Akgün, 2002) and Kırşehir–Tuzköy area (Akgün et al., 1995) in central Anatolia (Fig. 1). The palynomorph assemblage of the latest Serravallian–earliest Tortonian is characterized by abundant swamp (Taxodiaceae and Myricaceae) and mountain (*Pinus haploxylon* and *silvestris* types) forest elements. The riparian and mixed mesophytic forest elements, which are characterized by *Alnus*, *Platanus*/*Salix*, *Quercus*, *Carya* and *Ulmus* are predominant in the assemblage. The open vegetation elements (Poaceae, Chenopodiaceae, Compositae and Umbelliferae) increase from the early–middle Serravallian to the latest Serravallian–earliest Tortonian in the palynomorph assemblages of western and central Anatolia.

A tendency towards increasing proportions of arctotertiary elements such as *Betula*, *Alnus*, *Carpinus*, *Corylus*, *Fagus*, *Tilia* and species of the open vegetation (Poaceae, Chenopodiaceae and Compositae) and a tendency towards decreasing abundance of typical subtropical elements like *Engelhardia*, Sapotaceae and Cyrillaceae, is observed during the latest Serravallian–earliest Tortonian period. The change in palaeovegetation occurs slowly and gradually with minor fluctuations of the P/A–ratio during the latest Serravallian–earliest Tortonian periods (Fig. 2).

4.6. The early and middle Tortonian

Based on the palynological data, the Late Miocene is subdivided into two stratigraphic stages; the early and middle Tortonian, which are defined in the Elazığ and Sivas–Hafik areas of central Anatolia (Fig. 1). The early Tortonian sporomorph assemblage is determined in the Elazığ area and includes abundant mixed mesophytic and riparian forest elements (*Ulmus*, *Quercus*, *Castanea*, *Alnus*

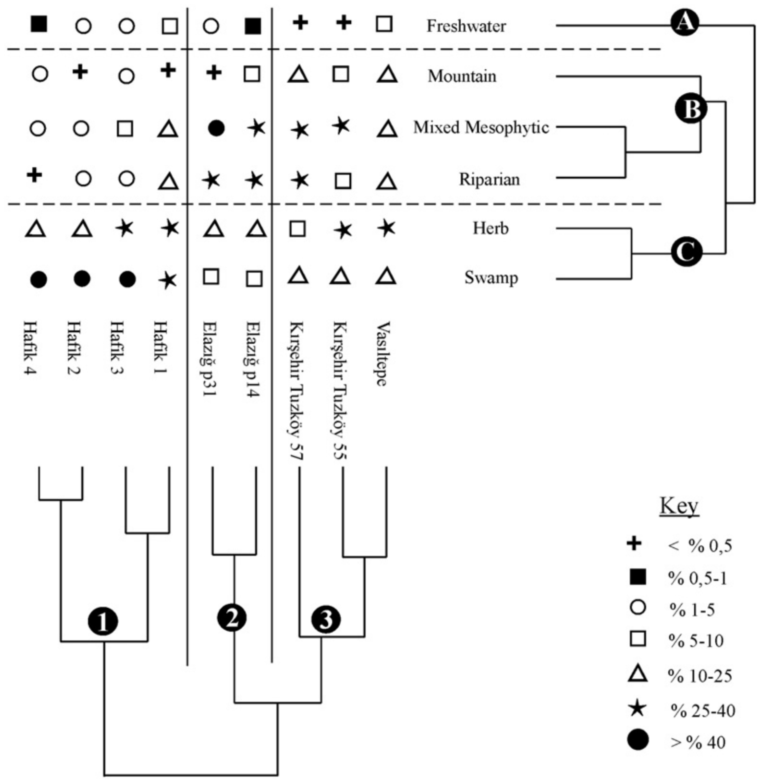


Fig. 8. Dendrograms of the latest Serravalian and earliest Tortonian, early and middle Tortonian for farthest neighbour cluster analysis of palaeocommunities (bottom) and samples (side), using Percent similarity.

and *Sambucus*). On the contrary, these forest elements are less frequently observed in Sivas–Hafik samples. The swamp (Taxodiaceae, Myricaceae) and mountain (*Pinus haploxylon* type) forest elements are represented by low percentage in the assemblages of Elazığ and Sivas–Hafik samples. The values of the open vegetation communities increase from the early to the middle Tortonian and are characterized by Poaceae, Compositae–Tubuliflorae and Liguliflorae, Umbelliferae and Chenopodiaceae. The percentage of open vegetation reaches its maximum value during the middle Tortonian period in central Anatolia.

The farthest neighbour cluster and detrended correspondences analyses have been used for the reconstruction of the palaeovegetation of the early and middle Tortonian in central Anatolia (Figs. 8 and 9). The dendrograms of Fig. 8 can be paired into three sample groups (1, 2 and 3) and into three palaeocommunities (A, B and C). In the sample dendrogram, assemblage 1 includes the samples of the middle Tortonian that are characterized by more abundant swamp forest and herb elements. Assemblage 2 is characterized by the early Tortonian samples and this assemblage predominantly consists of mixed mesophytic and riparian elements. Assemblage 3 includes the latest Serravallian and earliest Tortonian samples that are characterized by abundant mixed mesophytic, riparian and swamp forest elements.

The latest Serravalian–earliest Tortonian, early Tortonian and middle Tortonian samples have also been applied to detrended correspondence analysis (Fig. 9). Groups identified in cluster analysis have also been recognized in the plot. Assemblage 1 including the middle Tortonian samples has been grouped into the area of herb and swamp elements on the positive side of the axes 1 and 2. Both assemblage 2 comprising the early Tortonian samples and assemblage 3 including the latest Serravallian–earliest Tortonian samples have been condensed in the area of riparian, mountain and herb. Assemblages 2 and 3 occur on the positive side of axes 1 and 2 (Fig. 9).

During the early and middle Tortonian the percentage of arctotertiary elements was at a maximum while the percentage of palaeotropical elements was at a minimum. In the early and middle Tortonian period, the percentage of subtropical elements such as *Podacarpus*,

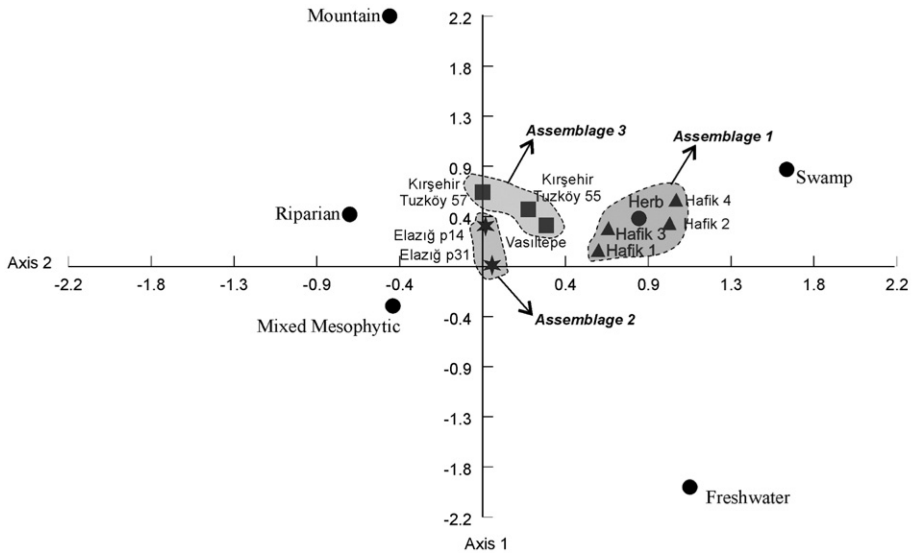


Fig. 9. Samples (black squares, triangles and stars) and palaeocommunities (black dots) for central Anatolia represented in the space of the first two axes using detrended correspondence analysis. Assemblage 3 is for the latest Serravalian–earliest Tortonian, assemblage 2 is for the early Tortonian and assemblage 1 is for the middle Tortonian.

Platycarya and Cyrillaceae was lower than in the early–middle Serravallian. In addition, the P/A–ratio decreased from the early to middle Tortonian (Fig. 2).

5. Palaeoclimatic evolution using the CA method

In this section, quantitative palaeoclimatic results derived from the CA based on the palynological assemblages of western and central Anatolia are presented (Table 2). These results and previous climatic data are evaluated. The leaf flora of the Soma basin has also been subjected to the CA method. The climatic data obtained is compared with the climatic data of western and central Anatolia.

5.1. The Chattian and Aquitanian

The climatic data of the latest Chattian and earliest and early Aquitanian have been obtained from the samples of the Kale–Tavas basin (Denizli–Kale and Tavas, Burdur–Kavak and Denizli–Kurbalık areas) in western Anatolia (Akgün and Sözbilir, 2001; Akgün et al., 2004).

In the latest Chattian palynomorph assemblage, 29 taxa were identified by Akgün and Sözbilir (2001) (Table 1 and Appendix A). The climatic evaluation is based on 21 taxa (Tables 1, 2). Quantitative results show that the values for MAT are between 16.5–21.1 °C, 5.5–13.3 °C for the CMT, 27.3–28.2 °C for the WMT and 1122–1355 mm for the MAP. These results indicate a warm subtropical climate during the latest Chattian. The palynoflora of the earliest Aquitanian was recorded in the Burdur–Kavak area by Akgün et al. (2004). The palynoflora includes 27 taxa, 24 of which were used for calculating the coexistence intervals (Tables 1, 2). For the MAT and CMT, the CA yields temperature from 17.2 to 20.8 °C and 5.5 to 13.3 °C respectively. Calculations for the WMT result in values from 27.3 to 28.1 °C. The interval of MAP is determined to be between 1217 and 1520 mm. Although the CMT and WMT are represented by similar values during the latest Chattian and earliest Aquitanian, the lower boundary of the MAT slightly increases in the earliest Aquitanian. For this reason, the climate of the earliest Aquitanian is warmer than the latest Chattian (Fig. 10 and Table 2).

For the early Aquitanian, the palynological data have been obtained by Akgün and Sözbilir (2001) from the Denizli–Kurbalık area. The authors defined 28 taxa. The palaeoclimatic parameters are based on 24 taxa (Tables 1, 2). The calculations are between 16.5 and 21.3 °C for the MAT, 5.5 and 13.3 °C for the CMT, 27.3 and 28.3 °C for the WMT, 1122 and 1520 mm for the MAP (Fig. 10 and Table 2). During the Chattian and Aquitanian, although the climatic variables for CMT and WMT are similar to each other, the lower boundary of the MAT decreases in the early Aquitanian. As a result, the temperature decreases and becomes similar to the climatic conditions of the Chattian.

According to Nagy (1990) and Planderová (1991), there was a warm subtropical climate during the Chattian and Aquitanian periods (Fig. 11). It is observed that the

Table 2
Coexistence intervals of the analyzed climatic parameters with the taxa causing the interval borders

	Latest Chattian	Earliest Aquitanian	Early Aquitanian	Latest Burdigalian	Langhian	Early–middle Serravallian	Early–middle Serravallian–earliest Tortonian	Early Tortonian	Middle Tortonian
	Western Anatolia Denizli–Kale, Tavas 21 taxa	Western Anatolia Burdur–Kavak 24 taxa	Western Anatolia Denizli–Kurbalık 24 taxa	Western Anatolia Balıkesir–Bigadiç Emet, Kırka, Kestelek 21 taxa	Western Anatolia Aydın–Başçayır Kuloğulları, 28 taxa	Western Anatolia Akhisar–Çıtak; Muğla–Yatağan; Manisa–Soma; Aydın–Söke, Şahinali, Büyük Menderes Region 27 taxa	Western Anatolia Muğla–Sekköy, Turgut; Aydın–Hasköy, Köşk, Sarayköy 23 taxa	Central Anatolia Elazig 10 taxa	Central Anatolia Sivas–Hafik 20 taxa
				Central Anatolia Samsun–Havza 29 taxa		Central Anatolia Ankara–Beypazarı; Kırşehir–Avcıköy; Konya–Ilgın; Çankırı basin 30 taxa	Central Anatolia Kırşehir–Tuzköy; Sivas–Vasıltepe 20 taxa		
MAT	16.5–21.1 °C Cycadaceae–*Carpinus*	17.2–20.8 °C *Trigonobalanus–Tilia*	16.5–21.3 °C Cycadaceae–*Carya*	17–21.3 °C *Trigonobalanus–Carya*	17–21.3 °C *Cathaya–Carya*	17–20.8 °C *Cathaya–Tilia*	12.9–20.8 °C Sapotaceea–*Tilia*	15.6–21.3 °C *Engelhardia–Carya*	16.5–20.8 °C Cycadaceae–*Tilia*
				17.2–20.8 °C *Trigonobalanus–Tilia*		17.2–20.8 °C *Trigonobalanus–Tilia*	17.2–20.8 °C *Revesia–Tilia*		
CMT	5.5–13.3 °C Cycadaceae–*Carya*	5.5–13.3 °C Cycadaceae–*Tilia*	5.5–13.3 °C Cycadaceae–*Carya*	6.2–13.3 °C *Cathaya–Carya*	6.2–13.3 °C *Cathaya–Carya*	9.6–13.3 °C Mastixiaceae–*Carya*	1.1–13.3 °C *Pinus silvestris–Carya* (0.9–1.1 °C) Sapotaceae–*Pinus*	5.0–13.3 °C *Engelhardia–Carya*	5.5–13.3 °C Cycadaceae–*Carya* (−0.1/1.1 °C) *Palmae–Pinus silvestri*
				6.2–13.3 °C *Cathaya–Carya*		7.7–13.1 °C Arecoideae–*Armeria*	5.5–13.3 °C Cycadaceae–*Carya*		
WMT	27.3–28.2 °C Cycadaceae–*Pteris*	27.3–28.1 °C Cycadaceae–Araliaceae	27.3–28.3 °C Cycadaceae–*Quercus*	26.5–27.9 °C *Cathaya–Nyssa*	26.5–28.1 °C *Cathaya*–Cupressaceae	27.3–27.9 °C Cycadaceae–*SabaI*	23.6–28.1 °C Sapotaceae–Cupressaceae	24.7–28.1 °C *Engelhardia*–Cupressaceae	27.3–28.1 °C Cycadaceae–Cupressaceae
				27.3–27.9 °C Cycadaceae–*SabaI*		27.3–27.7 °C Cycadaceae–*Armeria*	27.3–28.1 °C Cycadaceae–Araliaceae		
MAP	1122–1355 mm *Lygodium–Carpinus*	1217–1520 mm *Trigonobalanus*–Taxodiaceae	1122–1520 mm *Lygodium*–Taxodiaceae	1217–1322 mm *Trigonobalanus–Cathaya*	1183–1322 mm *Gleichenia–Cathaya*	1146–1322 mm *Cathaya–Cathaya*	1183–1520 mm *Gleichenia*–Taxodiaceae	823–1574 mm *Engelhardia*–Cupressaceae	887–1520 mm Cycadaceae–Taxodiacea
				1217–1322 mm *Trigonobalanus–Cathaya*		1217–1322 mm *Trigonobalanus–Cathaya*	1187–1574 mm *Revesia*–Cupresaceae		

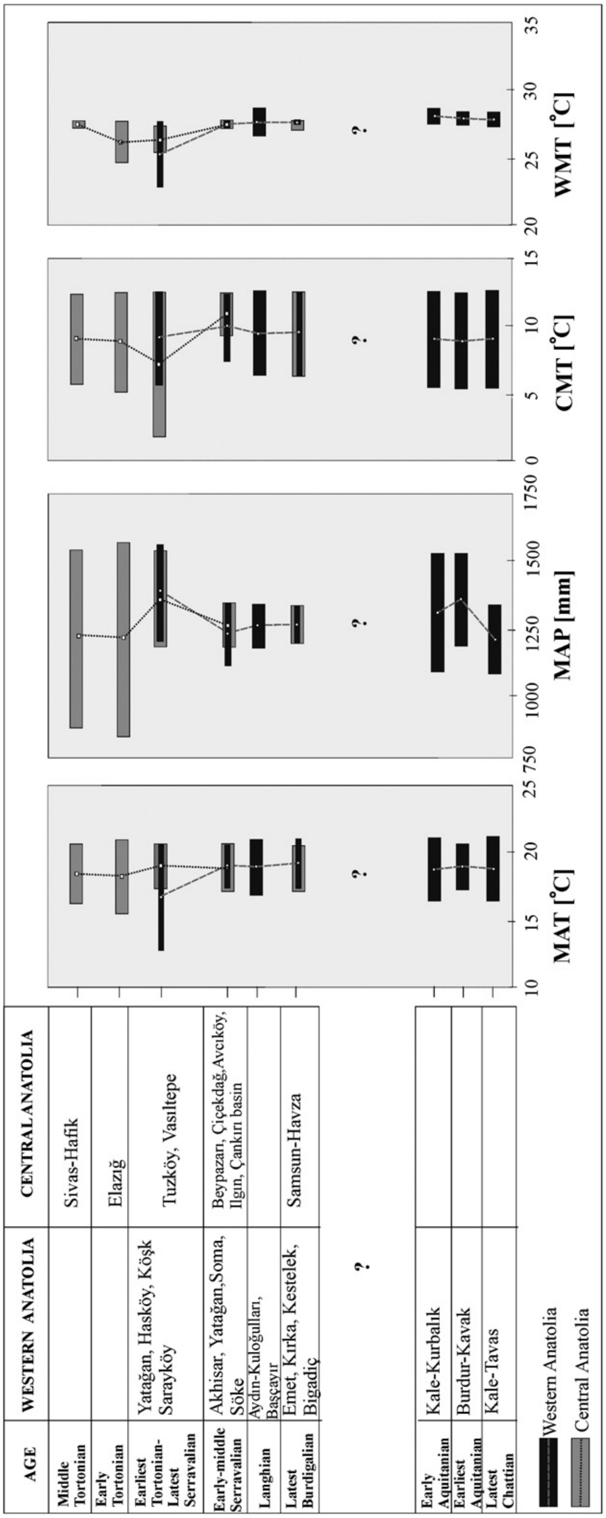


Fig. 10. Coexistence intervals derived from the samples of central and western Anatolia.

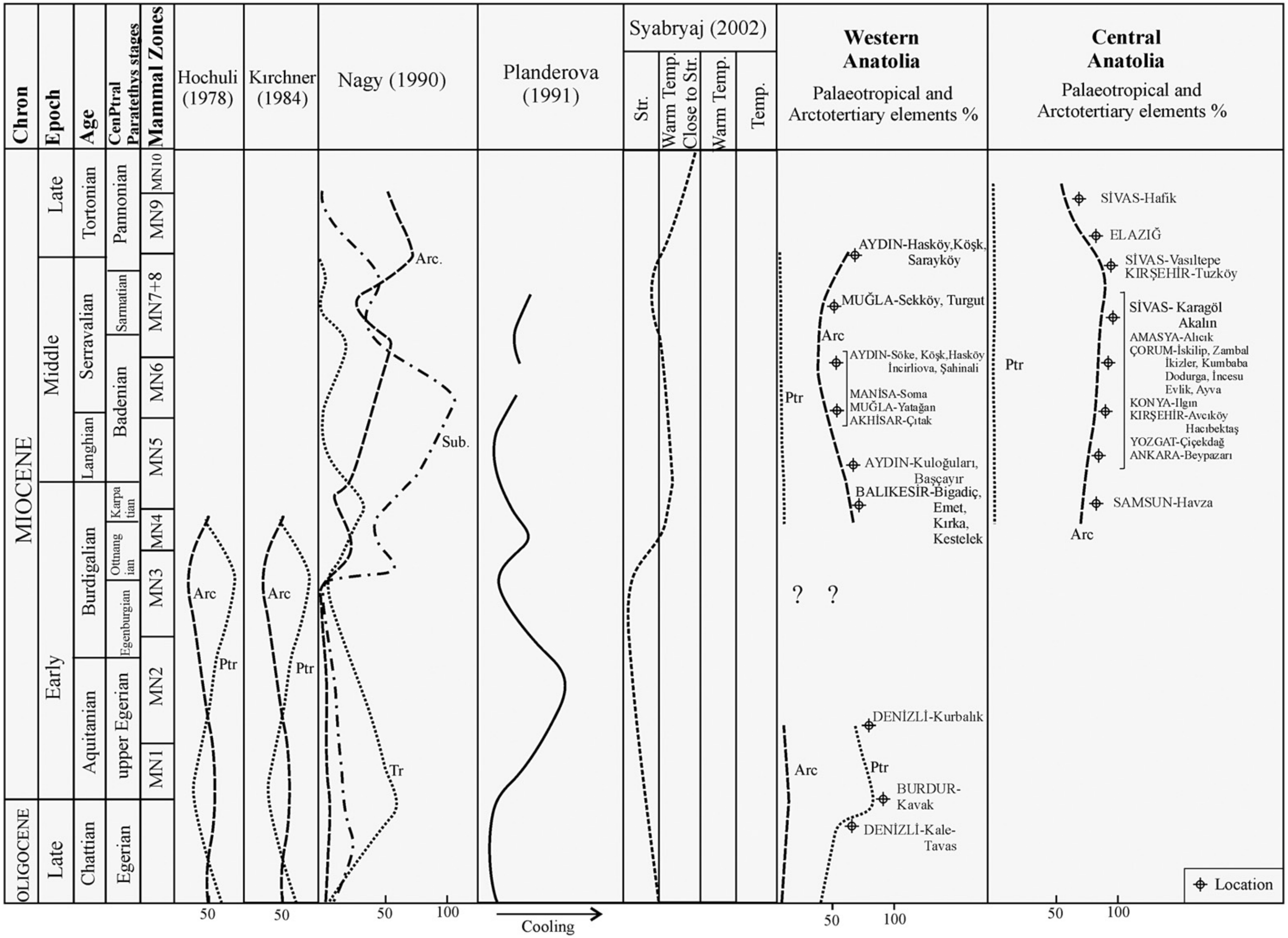


Fig. 11. The relative percentage of the palaeotropical and arctotertiary elements derived from the samples of western and central Anatolia and correlated with the previous studies (Hochuli, 1978; Kirchner, 1984; Nagy, 1990; Planderová, 1991; Syabryaj, 2002).

temperature at the Chattian and Aquitanian boundary reached a maximum value because of increasing palaeotropical elements. However, a decrease in temperature is estimated during the middle–late Aquitanian as evidenced from Nagy (1990) in the Hungarian Miocene and Planderová (1991) in Eastern and Central Europe. This climatic change shows similarities with the Chattian and Aquitanian of western Anatolia. In contrast, Hochuli (1978) from Austrian Molasse and Kirchner (1984) from Southern Bavarian Pitch Coal Mine recorded a warming during the early Aquitanian (Fig. 11).

5.2. The latest Burdigalian

The palynomorph data of the latest Burdigalian was obtained from the Bigadiç basin in western Anatolia (Akyol and Akgün, 1990) and Samsun–Havza area in central Anatolia (Kayseri and Akgün, 2002).

In western Anatolia, 26 taxa were identified and palaeoclimatic parameters are based on 21 taxa (Table 1 and Appendix A). The calculations are between 17.2 and 21.3 °C for MAT, 6.2 and 13.3 °C for the CMT, 26.5 and 27.9 °C for WMT and 1217 to 1322 mm for the MAP (Fig. 10 and Table 2).

In central Anatolia, the palaeoclimatic parameters are based on the 29 taxa in the samples of the Samsun–Havza area (Tables 1, 2). The obtained calculations are 17.2 to 20.8 °C for MAT, 6.2 to 13.3 °C for the CMT, 27.3 to 27.9 °C for WMT and 1217 to 1322 mm for the MAP (Fig. 10 and Table 2).

P/A–ratios have been observed to be high during the latest Burdigalian in western and central Anatolia but not as much as they were during the Chattian and Aquitanian (Fig. 2). During the latest Burdigalian, the lower boundary of the MAT and CMT increase while that for WMT decreases. Hence, results of P/A-ratios and CA data suggest that a warm subtropical climate was dominant during the latest Burdigalian. However, it was cooler than in the Chattian and Aquitanian period. The climatic results for western and central Anatolia are similar to the climatic data given by Nagy (1990) and Planderová (1991) (Fig. 11).

5.3. The Langhian

The palynological data were obtained from the Büyük Menderes region (Aydın–Başçayır and Kuloğulları) in western Anatolia by Akgün and Akyol (1999) (Table 1). In total, 36 taxa were identified by the authors (Appendix A). The palaeoclimatic reconstruction is based on 28 taxa (Table 1). The values are 17 to 21.3 °C for MAT, 6.2 to 13.3 °C for CMT, 26.5 to 28.1 °C for WMT and 1183 to 1322 mm for MAP (Fig. 10 and Table 2).

Although the CA results of the latest Burdigalian and Langhian are similar to each other, the P/A–ratio is low during the Langhian (Fig. 2). Therefore, the climate in the Langhian is subtropical rather than warm subtropical in western Anatolia.

5.4. The early and middle Serravallian

The palynological data for the early and middle Serravallian was analyzed from the Aydın–Köşk and Hasköy areas of Büyük Menderes region (Akgün and Akyol, 1999), Soma (Gemici et al., 1991), Akhisar–Çıtak area of Gördes (Akgün et al., 1986) and Muğla–Yatağan area of Yatağan basins in western Anatolia (Table 1). Palynological data of these basins consisted of 49 taxa. The palaeoclimatic reconstruction is based on 27 taxa (Tables 1, 2). The resulting coexistence interval for the MAT ranges from 17 to 20.8 °C. The intervals for the CMT and WMT are determined as 9.6 to 13.3 °C and 27.3 to 27.9 °C, respectively. For the MAP, the CA yields values between 1183 and 1322 mm (Fig. 10 and Table 2).

In central Anatolia, the palynoflora was recorded from the Konya–Ilgın, Ankara–Beypazarı, Kırşehir–Avcıköy, Hacıbektaş and Çankırı basin (Akgün et al., 1995; Karayiğit et al., 1999; Kayseri, 2002; Kayseri and Akgün, 2002; Akgün et al., 2002). The palynoflora includes 62 taxa. The palaeoclimatic reconstruction is based on 30 taxa (Tables 1, 2 and Appendix B). For the MAT and CMT, the CA yields temperature from 17.2 to 20.8 °C and 7.7 to 13.1 °C, respectively. Calculations for the WMT result in values from 27.3 to 27.7 °C. The interval of MAP is determined to be between 1217 and 1322 mm (Fig. 10 and Table 2).

In addition, the leaf flora and palynoflora from the Soma basin analyzed by Nebert (1978) and Gemici et al. (1991) have also been reevaluated here. The leaf flora of the Soma basin contains 103 taxa, 52 taxa of which were used for calculating the coexistence intervals (Appendix C). The obtained values are 15.3 to 16.5 °C for the MAT, 2.7 to 4.8 °C for the CMT and 25.7 to 26 °C for the WMT. The MAP lies between 1036 and 1237 mm (Fig. 12 and Table 3).

The palynoflora of the samples collected from the Soma basin includes 30 taxa (Appendix A). The palaeoclimatic parameters are based on 10 taxa. The calculations are 16.5 to 21.3 °C for MAT, 4.8 to 13.3 °C for the CMT, 26 to 27.9 °C for WMT and 629 to 1520 mm for the MAP (Fig. 12 and Table 3). The coexistence intervals of the leaf flora and palynoflora for the Soma basin show different climatic values and do not overlap on MAT, CMT and WMT. The coexistence intervals obtained from the leaf flora indicates the lower climatic values than the palynoflora (Fig. 12). In general, the Coexistence Approach on the basis of palynoflora yields a wider coexistence interval than on leaf flora (Mosbrugger and Utescher, 1997; Liang et al., 2003). This is believed to be related to the fact that NLRs of Tertiary palynomorphs are frequently determined only to family whereas NLRs of Tertiary leaves are more reliably identified to specific and generic level (Mosbrugger and Utescher, 1997). The lower floral diversity provides a wide coexistence interval leading to lower climatic resolution. The obtained climatic values based on palynological data from the Soma basin are on 10 taxa and hence of lower climatic resolution. The leaf flora gives a narrow interval and lower climatic results for all temperature related climatic parameters (Fig. 12). On the other hand, the MAP coexistence interval of leaf flora and palynoflora overlap (Fig. 12).

During the early and middle Serravallian, although the ratio of palaeotropical and arctotertiary elements is represented by lower values in western and central Anatolia, the climate is in subtropical character based on the maximum occurrences of subtropical elements and the result of the CA.

5.5. The latest Serravallian–earliest Tortonian

The palynoflora was obtained from the Yatağan basin (Muğla–Sekköy and Turgut area) (Erdei et al., 2002) and Aydın–Hasköy, Köşk and Sarayköy of the Büyük Menderes region by Akgün and Akyol (1999) in western Anatolia and comprises 49 taxa (Table 1 and Appendix A). 23 taxa of the palynoflora could be used for calculating the coexistence interval (Tables 1, 2). For the MAT, the CA yields temperature from 12.9 to 20.8 °C. The CMT values

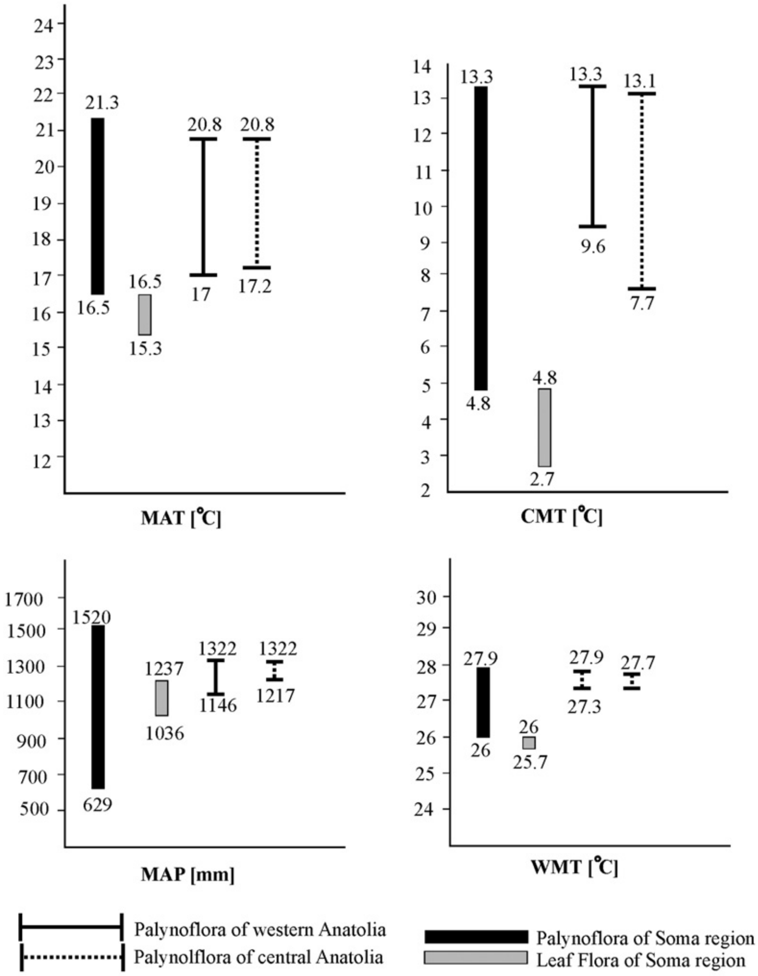


Fig. 12. Palaeoclimate comparison based on the Soma region pooled palyno and leaf floras data (Nebert, 1978; Akgün et al., 1986; Gemici et al., 1991).

Table 3
Coexistence intervals of the Soma region pooled palynoflora and leaf flora (Nebert, 1978; Akgün et al., 1986; Akgün, 1993)

	Palynoflora	Leaf flora
	27 taxa	52 Taxa
MAT	16.5–21.3 °C Sabal–Carya	15.3–16.5 °C Ziziphus ziziphoides–*Populus* cf. *balsamoides*
CMT	4.8–13.3 °C *Sabal–Carya*	2.7–4.8 °C *Myrica lignitum– Populus* cf. *balsamoides*
WMT	26–27.9 °C *Sabal–Sabal*	25.7–26 °C *Ulmus carpinoides–Pinus palaeostrobus*
MAP	629–1520 mm Sabal–Taxodium	1036–1237 mm *Myrica lignitum– Populus* cf. *balsamoides*

show a low climate resolution between 1.1 and 13.3 °C. However, the CMT intervals between 0.9–1.1 °C also occur. Calculations for the WMT result in values from 23.6 to 28.1 °C. The interval of MAP is determined to be between 1183 and 1520 mm.

The palynoflora of the latest Serravallian and earliest Tortonian in central Anatolia was defined from the Sivas–Vasıltepe and Kırşehir–Tuzköy areas (Akgün et al., 1995; Kayseri, 2002; Kayseri and Akgün, 2002). In total, 37 taxa were identified by the authors (Table 1 and Appendix B). The palaeoclimatic reconstruction is based on 20 taxa (Tables 1, 2). The values are 17.2 to 20.8 °C for the MAT, 5.5 to 13.3 °C for the CMT, 27.3 to 28.1 °C for the WMT and 1187 to 1524 mm for the MAP (Fig. 10 and Table 2).

The climate became colder from the middle to late Serravallian. This trend resulted in the dominance of arctotertiary elements, and falling of the P/A–ratio in samples from western and central Anatolia. A falling of the lower boundaries on the MAT, CMT and WMT has been observed in the latest Serravallian–earliest Tortonian. This also shows that the climate changed from subtropical to warm temperate. However, the values of MAP remained similar throughout the middle and late Serravallian (Table 2).

5.6. The early and middle Tortonian

The palynomorph assemblage of the early Tortonian in central Anatolia is recorded from the Elazığ area and the palaeoclimatic parameters are based on 10 taxa (Tables 1, 2). The calculations obtained are 15.6 to 21.3 °C for MAT, 5.0 to 13.3 °C for the CMT, 24.7 to 28.1 °C for WMT and 823 to 1574 mm for the MAP. The middle Tortonian assemblage is determined in the Sivas–Hafik area of the Sivas basin. 27 taxa were recorded (Table 1 and Appendix B). Palaeoclimatic parameters are based on 20 taxa for the middle Tortonian (Tables 1, 2). The calculations are between 16.5 and 20.8 °C for MAT, 5.5 and 13.3 °C for the CMT, 27.3 and 28.1 °C for WMT and 887 to 1520 mm for the MAP (Fig. 10 and Table 2).

The P/A–ratio is low in the samples of early–middle Tortonian. As the percentage of subtropical elements decrease, the percentage of arctotertiary elements increase and this causes a decrease in the lower limit of the MAT in central Anatolia. During this period the climate was warm temperate. Although the MAP has a wide coexistence interval, a decrease in the lower limit of MAP is conspicuous. During the middle Tortonian, the dominance of arctotertiary elements indicating open vegetation and the presence of a grazer *Ceratotherium neumayri* Osborn living in open areas (Akgün et al., 2002) reflect the warm temperate climate including seasonally dry conditions.

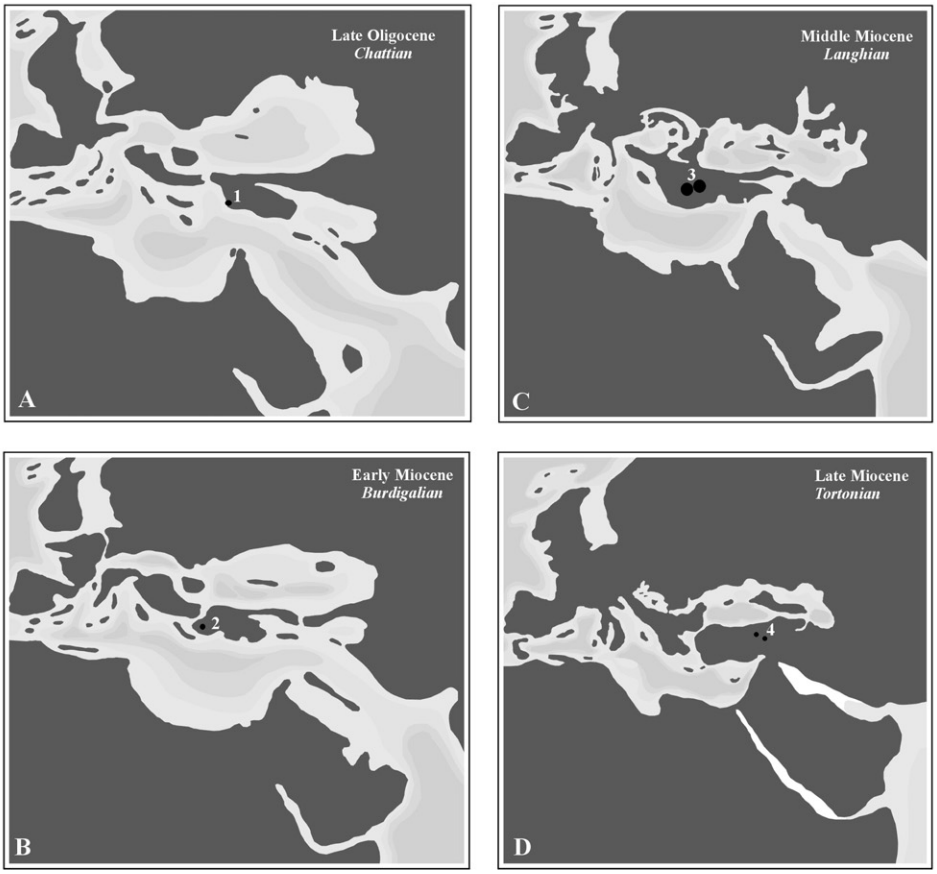
6. Palaeogeography

In this section, we have tried to make an approximation to the palaeogeography of western and central Anatolia based on the palaeoenvironmental data for the Late Oligocene–Late Miocene time interval. During the Oligocene, there was a broad connection between the Indian Ocean, Mediterranean and Paratethys seas (Harzhauzer and Piller (this volume) (Fig. 13A, B and C). The deposition of widespread reefal limestones in the Early Miocene both in Turkey and neighboring countries indicate that warm climatic conditions prevailed during this time in this part of the world (Görür et al., 1995).

Palynological data display four clear vegetational changes through the Oligocene–Miocene period as divided into the Late Oligocene–earliest Early Miocene (Chattian and Aquitanian), Early Miocene, Middle Miocene and Late Miocene.

The northern border of the marine environment was defined by a line connecting the cities of Denizli, Burdur and Isparta (Eğridir) by Luttig and Steffens (1976). It indicates that the Kale–Tavas basin was a depositional terrestrial environment under marine influence based on presence of marine dinoflagellate cycts during the Chattian and Aquitanian period (Fig. 13A). Coarse clastic materials at the base of the Kale–Tavas basin were derived from a structural high formed of ophiolitic materials (Akgün and Sözbilir, 2001). The high was located to the south of the basin (Gürer and Yılmaz, 2002).

In the Early Miocene, the palaeogeography of Turkey was an erosional highland with fault bounded basins. The palaeovegetational data substantiate the uplift of Turkey in the Late Aquitanian–Late Burdigalian period (Fig. 13B). The Anatolian highlands decreased in elevation towards



A. Late Oligocene (Chattian) — 1. Kale-Tavas basin (Tavas, Kurbalık and Kavak areas) in western Anatolia

B. Early Miocene (Burdigalian) — 2. Bigadiç basin (Bigadiç, Emet and Kırka areas) and Büyük Menderes region (Kuloğulları area) in western Anatolia and Çankırı basin (Havza area) in central Anatolia.

C. Middle Miocene (Langhian and early-middle Serravalian) — 3. Büyük Menderes Region (İncirliova, Hasköy, Söke and Şahinali areas), Soma, Gördes and Yatağan basins in western Anatolia; Çankırı basin (Alıcık, Ayva, Evlik, Dodurga İkizler, İncesu, İskilip, Kumbaba, Zambal, Sivas-Akalın, Karagöl and Vasıltepe areas), Çiçekdağ (Yozgat), Avcıköy and Kızılöz (Kırşehir), Ilgın (Konya), Beypazarı(Ankara) areas in central Anatolia.

D. Late Miocene (early and middle Tortonian) — 4. Elazığ and Hafik (Sivas) areas in central Anatolia.

Fig. 13. Palaeogeographic maps from the Late Oligocene to Late Miocene, showing the estimated positions of coal-bearing basins.

the east and south and descended to the Mediterranean. Northern Arabian platform was covered by a shallow sea connecting the Mediterranean to the Indian ocean in which deposition of reefal limestones indicates warm climatic conditions (Erol, 1981; Görür et al., 1995). The climatic values defined on the basis of palynological data in this study display warm subtropical conditions during the Early Miocene.

After the withdrawal of the sea in the Middle Miocene, sedimentation occurred in the terrestrial environment. The tectonic and sedimentary conditions seem to have continued during the Middle Miocene and the grabens increased during this period in both number and areal extent in western Anatolia (Görür et al., 1995). The Middle Miocene vegetation determined from many locations of western and central Anatolia is dominated by swamp and mixed mesophytic forests growing under the subtropical conditions (Fig. 13C).

The Arabian platform collided with Laurasia due to the elimination of the Bitlis ocean in the Middle Miocene

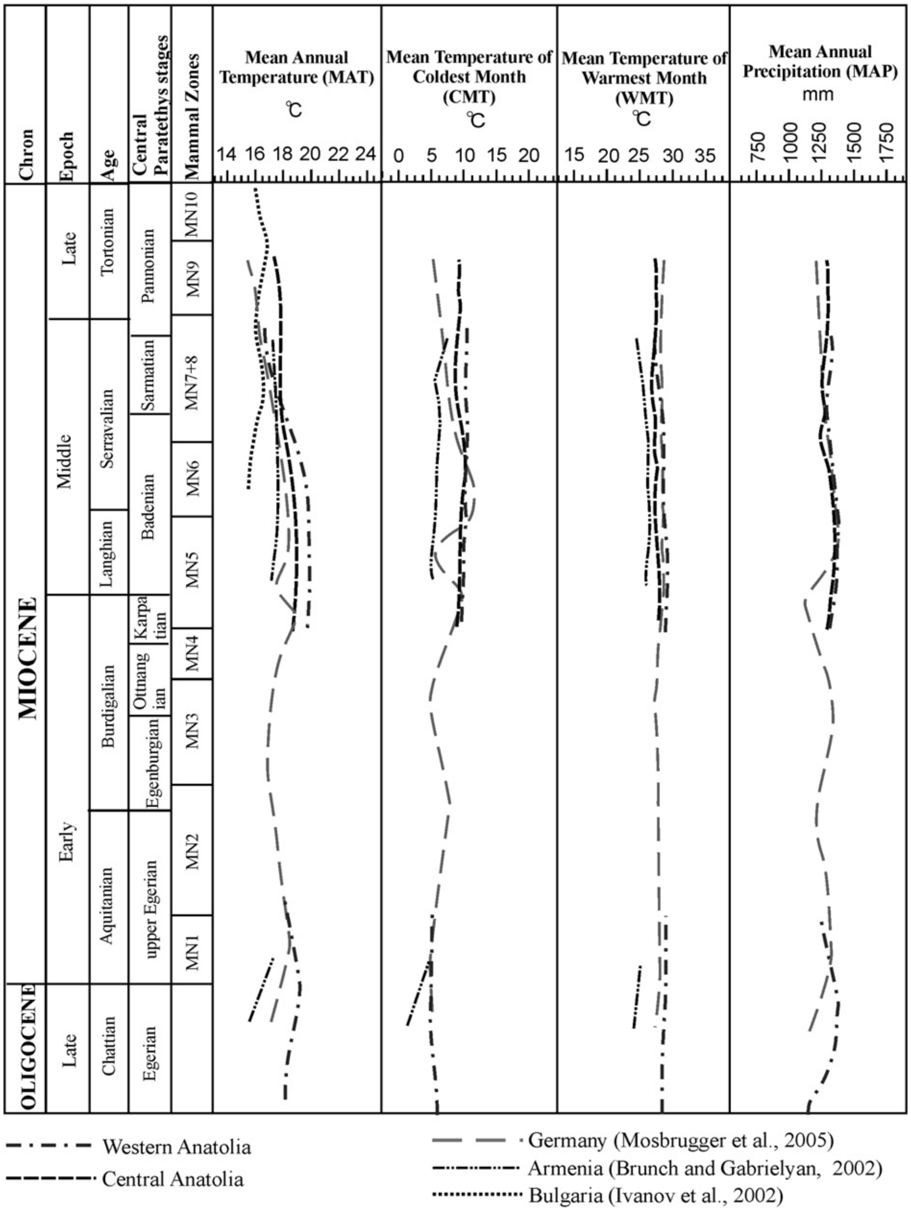


Fig. 14. Records for MAT, CMT, WMT and MAP as calculated by the CA in western and central Anatolia. The figure also correlates with the palaeoclimatic variations between Turkey and neighbour countries (Germany, Armenia and Bulgaria).

(Görür and Tüysüz, 2001). The westward escape tectonic regime of Turkey started during the Late Miocene along with the formation of the North and East Anatolian transform fault (Şengör et al., 1985). In eastern Anatolia, this regime generated a number of large ramp–valley basins (Görür and Tüysüz, 2001). The late Middle and Late Miocene vegetation in central Anatolia that developed under warm temperate climatic conditions is indicated by the dominance of a mountain forest assemblage while the vegetation is generally characterized by the dominance of mixed mesophytic and swamp forest assemblages in western Anatolia (Fig. 13D). In the light of these data, it can be said that the elevation of the central Anatolia was higher than in western Anatolia during the Middle–Late Miocene. On the other hand, the percentages of the herb species such as Compositae, Chenopodiaceae and Poaceae increased from the Middle Miocene to the Late Miocene. Therefore, it can be said that open vegetation areas from the Middle Miocene to Late Miocene were extended.

7. Discussions and conclusions

The well preserved and diverse palynofloras from western and central Anatolia allowed us to reconstruct the vegetation and climate evolution. We have obtained the first quantitative climatic reconstructions for the palynofloras of western and central Anatolia during the Late Oligocene–Miocene period.

From the palaeovegetational point of view, the swamp, mixed mesophytic and riparian forests communities were dominant during the Late Oligocene–Miocene in western and central Anatolia. Based on the palaeovegetational data, the palaeogeographic properties of western and central Anatolia can be classified as follows in ascending order; 1) the presence of the sea in southwest Anatolia during the Chattian and Aquitanian and accumulation of near shore sediments 2) dominance of terrestrial environments due to increased elevation of Anatolia during the Early–Middle Miocene 3) continuity of terrestrial conditions on account of increasing elevation during the Late Miocene. The palaeovegetation in the eastern part of central Anatolia indicates a higher palaeotopography than western Anatolia.

The CA results of central and western Anatolia are correlated with the results of Germany, Bulgaria and Armenia (Bruch and Gabrielyan, 2001; Syabryaj, 2002; Mosbrugger et al., 2005) (Fig. 14). The MAT values of western Anatolia are generally the same during the Late Chattian and early Aquitanian but there is an increase around the late Chattian–early Aquitanian boundary. The MAT values are high from the late Burdigalian to middle Serravalian. Nevertheless, a clear decreasing trend is observed in the late Serravalian. The MAT values of central Anatolia are lower than values of western Anatolia and these low values are observed during the late Burdigalian–middle Serravalian period. These low values tend to increase during late Serravalian and early Tortonian. Generally, the MAT values of Germany, Bulgaria and Armenia are lower than the values of western and central Anatolia during the Oligocene and Miocene period. The MAT values decrease in Germany during the late Burdigalian and early Langhian period, but these reductions are not observed in Anatolia. Besides, in the late Serravalian period the MAT values of Armenia are a bit higher than the values of western Anatolia (Bruch and Gabrielyan, 2001) (Fig. 14).

Recent studies show that the climatic variations are based on the change of the CMT (Utescher et al., 2000). Conversely, MAT and WMT did not undergo an important change during the Oligocene and Miocene time. In addition, the precipitation is low with little over 1000 mm for the most of the intervals (Utescher et al., 2000; Mosbrugger et al., 2005). In the Kale–Tavas basin, the CMT values are the same (5.5–13.3 °C) as during the latest Chattian and Aquitanian. In addition, the lower boundary of MAT increases from the latest Chattian to the earliest Aquitanian and decreases in the Aquitanian period (Fig. 14 and Table 2). The change in MAT values in the earliest Aquitanian is also observed in the P/A–ratios and it is seen that palaeotropical elements increased during this time. For this reason, the climate should have been warm subtropical in the latest Chattian and earliest Aquitanian. Mosbrugger et al. (2005) indicate a temperature peak from the Lower Rhine Embayment in the latest Chattian. The climatic results defined in this study also support a temperature peak at that time. It also corresponds to the Late Oligocene warming from isotopic records (Zachos et al., 2001). While CMT values are similar for Germany and Anatolia during the latest Burdigalian and early Langhian periods, the increasing lower boundary in the CMT is noticeable and is represented by 9.6–13.3 °C in western and 7.7–13.1 °C in central Anatolia during the early and middle Serravallian period. This warm time span corresponds to the middle Miocene climatic optimum that is globally observed (Utescher et al., 2000; Mosbrugger et al., 2005). The CMT values decrease from middle Serravalian to early Tortonian. The subtropical climate during the early–middle Serravalian changed to warm temperate in the Tortonian. This cooling was clear in the Middle Tortonian. The climate was warm temperate and included dry seasons during the Late Miocene. The CMT values of Armenia are much lower than the values of Germany and Turkey (Fig. 14).

The WMT and MAP values are similar for western, central Anatolia and Germany, but the WMT values of Armenia are lower. Besides, decreasing MAP values of the Tortonian period are clear in Anatolia and Germany (Fig. 14).

Acknowledgements

We would like to thank Dr. Angela Bruch (Frankfurt–Germany) for her help through the course of this work. Financial support was provided by Dokuz Eylül University, Graduate School of Natural and Applied Science (AFS, high licenses project numbers: 0922.01.01.12 and project numbers: 02KB.FEN.046) and Science and Technical Research Council of Turkey (TUBİTAK grant code 101Y133). We thank to two anonymous referees for their valuable contributions. This work is part of the NECLIME programme (Neogene climate evolution in Eurasia).

Appendix A

Taxon list of the pollenflora used in the CA for western Anatolia (Palaeoclimatic Proxy contain Palaeotropical: Ptr.,Arctotertiary: Arct., Subtropical: Str., Cosmopoliatan: Comp. vegetation type consist of the Mountain: Moun., Mixed Mesophytic: Mix. Mesp., Riparian: Rip., Freshwater: Fresh., Swamp: Swamp, Open Vegetation element: Herb.)

Age				Latest Chattian	Earliest Aquitanian	Early Aquitanian	Latest Burdigalian	Langhian		Early-middle Serravallian				Latest Serravallian–earliest Tortonian	
Western Anatolia location				Kale–Tavas Basin			Bigadiç Basin	Büyük Menderes region		Gördes Basin	Büyük Menderes Region	Soma Basin	Yatağan Basin	Yatağan Basin	Büyük Menderes region
Fossil–taxon		Palaeoclimatic proxy	Vegetation type	Denizli–Kale, Tavas	Burdur–Kavak	Denizli–Kurbalık	Balıkesir–Bigadiç, Emet, Kırka, Kestelek	Aydın–Başçayır	Aydın–Kuloğulları	Akhisar–Çıtak	Aydın–Söke, Köşk, Hasköy, İncirliova Şahinali	Manisa–Soma	Muğla–Yatağan	Muğla–Sekköy, Turgut	Aydın–Hasköy, Köşk, Sarayköy
Aceripollenites striatus	Acer	Arct.	Mix. Mesp.										+		
Baculatisporites primarius	Osmuncaceae	Comp.	Swamp						+	+	+		+		+
Baculatisporites cf. primarius													+		+
Baculatisporites gemmatus															+
Baculatisporites microornatus										+			+		
Baculatisporites nanus													+		
Caryapollenites simplex	Carya	Arct.	Mix. Mesp.	+	+	+	+	+	+	+	+	+	+	+	+
Cedripites cedroides	Cedris	Arct.	Moun.										+		+
Cingulatisporites macrospecious	Pteridaceae	Comp.	Swamp				+		+	+		+			+
Cingulatisporites viliosus										+					
Concavisporites sp.	Unknown	x	x											+	+
Corsinipollenites oculis noctis	Onagraceae	Arct.	? Swamp.												+
Cupressacites cuspidataeformis	Cupressaceae	Arct.	Mix. Mesp.												+
Cupressacites insulipapillatus				+											
Cycadopites cycadoides	Cycadoceae	Ptr.	Mix. Mesp.										+		
Cycadopites minor													+		
Cycadopites gracilis					+								+		
Cycadopites cf. gracilis															
Cycadopites sp.				+	+	+							+	+	+
Cyperaceaepollis piriformis	Cyperaceae	x	Fresh.	+		+									
Dicolpopollenites kalewensis	*Calamus*	Ptr.	Fresh.	+		+									
Echigraminidites moravicus	Lemnaceae	Comp.	Fresh.						+		+				+
Echinatisporites cf. bockwitzensis	Unknown	x	x	+											
Echinatisporites sp.				+	+		+								
Ephedripites claricristatus	Ephedraceae	Comp.	Herb.										+		
Ephedripites fusiformis													+		
Ephedripites landenensis													+		
Ephedripites tertiarius															+
Ephedraceae type									+		+		+		+

Graminidites gramineoides	Poaceaea						+	+	+	+	+	+	+	+	+
Graminidites cf. laevigatus													+		+
Graminidites sp.											+	+			
Graminidites subtiliglobosus													+		+
Monoporopollenites solaris										+					
Gleichenia type	Gleicheniaceae	Ptr.	? Swamp.				+		+	+					+
Ilexpollenites iliacus	Ilex	Arct.	Mix. Mesop.							+					
Ilexpollenites margaritatus									+				+		
Ilexpollenites microiliacus										+		+	+		
Inaperturopollenites concedipites	Taxodiaceae	Arct.	Swamp	+	+	+							+		
Inaperturopollenites hiatus							+		+	+	+	+	+		+
Inaperturopollenites incertus										+					
Inaperturopollenites magnus				+					+		+	+	+		+
Inaperturopollenites verrucosus												+			
Inaperturopollenites dubius	Cupressaceae		Mix. Mesp.					+	+	+	+	+	+	+	+
Inaperturopollenites polyformosus	*Sequoia*	Arct.	Rip.		+		+		+	+	+	+			
Inaperturopollenites sp.	Unknown	x	x			+			+						
Intratriporopollenites indubitabilis	*Tilia*	Arct.	Mix. Mesp.										+		
Intratriporopollenites instructus				+	+				+	+	+		+		+
Ischyosporites asolidus	Schizaceae	Ptr.	? Swamp	+											
Laevigatosporites haardti haardti	Polypodiaceae	Comp.		+		+	+	+	+	+	+	+	+	+	+
Laevigatosprites sp.														+	+
Leiotriletes microadriennis	Schizaceae	Ptr.		+		+			+	+	+			+	+
Leiotriletes adriennis				+		+									
Leiotriletes dorogensis				+		+									
Leiotriletes maxoides maxoides					+										
Leiotriletes triangulus					+										
Leiotriletes sp.					+										
Longapertites sp.	Unknown	x	x		+										
Lonicerapollis gallwitzi	*Lonicera*	Arct.	Rip. or Mix. Mesp.												+
Lusatisporis punctatus	*Selaginella*	Arct.	Rip.					+							
Momipites punctatus	*Engelhardia*	Ptr. or Str.	Mix. Mesp.		+								+		+
Momipites quietus					+										
Monocolpopollenites areolatus retareolatus	*Sabal*	Arct.	x									+			
Monocolpopollenites tranquillus	*Palmae*	Ptr.	Mix. Mesp.	+									+		

(continued on next page)

Appendix A (*continued*)

Age				Latest Chattian	Earliest Aquitanian	Early Aquitanian	Latest Burdigalian	Langhian		Early-middle Serravallian				Latest Serravallian–earliest Tortonian	
Western Anatolia location				Kale–Tavas Basin			Bigadiç Basin	Büyük Menderes region		Gördes Basin	Büyük Menderes Region	Soma Basin	Yatağan Basin	Yatağan Basin	Büyük Menderes region
Fossil–taxon		Palaeoclimatic proxy	Vegetation type	Denizli–Kale, Tavas	Burdur–Kavak	Denizli–Kurbalık	Balıkesir–Bigadiç, Emet, Kırka, Kestelek	Aydın–Başçayır	Aydın–Kuloğulları	Akhisar–Çıtak	Aydın–Söke, Köşk, Hasköy, İncirliova Şahinali	Manisa–Soma	Muğla–Yatağan	Muğla–Sekköy, Turgut	Aydın–Hasköy, Köşk, Sarayköy
Monocolpopollenites sp.	Unknown	x	x										+		
Monogemmites pseudosetarius	Nymphaceae		Fresh.	+			+	+	+	+	+	+	+	+	+
Myrtaceidites mesonesus	Myrtaceae	Ptr. or Str.	Rip.										+		
Myrtaceidites sp.					+										
Periporopollenites microporatus	Chenopodiaceae	Comp.	Herb.									+	+		
Periporopollenites multiporatus							+	+	+		+		+		+
Periporopollenites stigmosus							+				+		+		+
Periporopollenites sp.													+		
Pityosporites alatus	Cathaya sp.	Arct.	Moun.orMix.										+		+
Cathaya type			Mesp.				+								
Pityosporites strobipites	Pinus sp.			+		+									+
Pityosporites microalatus	*Pinus haploxylon*			+	+	+	+	+	+	+	+	+	+	+	+
Pityosporites labdacus	*Pinus silvestris*				+		+		+	+	+	+	+		+
Pityosporites libellus	*Podacarpus* sp.	Ptr. or Str.					+		+	+			+		+
Platycaryapollenits miocenicus	*Platycarya*	Ptr.	Mix. Mesp.	+											
Plicatopollis plicatus	Juglandaceae	Arct.			+										
Polypodiaceoisporites sp.	Polypodiaceae	Comp.	? Swamp												
Polypodiaceoisporites marxheimensis				+											
Polypodiaceoisporites graccilimus				+											
Polypodiaceoisporites seidewitzensis				+											
Polypodiaceoisporites verruspeciousus				+	+										
Polyporopollenites carpinoides	*Carpinus*	Arct.	Mix. Mesp.	+									+		+
Polyporopollenites undulosus	*Ulmus*			+		+	+	+	+	+	+	+	+	+	+
Polyporpollenites fragilis	Unknown	x	x										+		
Polyvestibulopollenites verus	*Alnus*	Arct.	Rip. or Swamp	+	+		+	+	+	+	+	+	+		+
Porocolpopollenites rotundus	*Symplocos* sp.	Arct.	x							+					
Porocolpopollenites vestibulum	Unknown	x	x	+		+			+	+	+				+
Pterocaryapollenites stellatus	*Pterocarya*	Arct.	Mesp.	+					+	+	+	+	+		+

Punctatisporis sp.	Unknown	x	x							+	+				
Quercoidites asper										+		+	+		
Quercoidites henrici	Quercus			+	+	+	+	+	+	+	+	+	+		+
Quercoidites microhenrici		Arct.	Mix. Mesp.	+	+	+	+	+	+	+	+	+	+	+	+
Quercopollenites robur															+
Retitriletes sp.	*Lycopodium* sp.													+	+
Revesiapollenites triangulus	*Reevesia*	Ptr. or Str.	Mix. Mesp.		+										
Ruhuspollenites ornatus	*Rhus*	Arct.	Mix. Mesp.			+									
Sparganiaceaepollenites neogenicus	Sparganiaceae	Arct.	Fresh.						+		+		+		+
Sparganiaceaepollenites polygonalis				+							+				+
Stereisporites stereoides															+
Stereisporites minor	Sphagnaceae	Ptr.	Fresh.	+											
Stereisporites sp.							+								
Subtriporopollenites anulatus nanus	*Carya*	Arct.	Mix. Mesp.	+		+	+								
Subtriporopollenites intraconstans				+											
Tetracolporopollenites abditus										+			+		
Tetracolporopollenites manifestus ellipsoides				+			+		+	+	+	+	+		
Tetracolporopollenites microellipsus						+	+			+	+	+	+		
Tetracolporopollenites microrhombus	Sapotaceae			+		+	+		+						
Tetracolporopollenites obscurus		Ptr.	Mix. Mesp.	+				+	+						+
Tetracolporopollenites sapotoides													+		
Tetracolporopollenites ericus					+										
Tetracolporopollenites sp.					+										
Triatriopollenites bituitus				+	+	+	+	+	+	+	+	+	+	+	+
Triatriopollenites coryphaeus	*Myrica* sp.			+	+	+	+	+	+	+	+	+	+	+	+
Triatriopollenites pseudorurensis							+			+	+				+
Triatriopollenites rurensis		Arct.	Swamp	+	+	+	+	+		+	+	+	+		+
Triatriopollenites myricoides	Myricaceae					+				+	+		+		
Triatriopollenites plicatus				+		+			+	+	+	+			
Triatriopollenites concavus				+		+									
Triatriopollenites araboratus		x	x							+					
Triatriopollenites rurobituitus	Unknown									+					
Triatriopollenites sp.					+					+			+		+
Tricolpopollenites densus	*Quercus*	Arct.	Mix. Mesp.	+	+	+	+	+	+	+	+	+	+	+	+

(continued on next page)

Appendix A (*continued*)

Age				Latest Chattian	Earliest Aquitanian	Early Aquitanian	Latest Burdigalian	Langhian		Early-middle Serravallian				Latest Serravallian–earliest Tortonian	
Western Anatolia location				Kale–Tavas Basin			Bigadiç Basin	Büyük Menderes region		Gördes Basin	Büyük Menderes Region	Soma Basin	Yatağan Basin	Yatağan Basin	Büyük Menderes region
Fossil–taxon		Palaeoclimatic proxy	Vegetation type	Denizli–Kale, Tavas	Burdur–Kavak	Denizli–Kurbalık	Balıkesir–Bigadiç, Emet, Kırka, Kestelek	Aydın–Başçayır	Aydın–Kuloğulları	Akhisar–Çıtak	Aydın–Söke, Köşk, Hasköy, İncirliova Şahinali	Manisa–Soma	Muğla–Yatağan	Muğla–Sekköy, Turgut	Aydın–Hasköy, Köşk, Sarayköy
Tricolpopollenites liblarensis									+	+	+	+	+		+
Tricolpopollenites liblarensis liblarensis	Fagaceae				+	+	+								
Tricolpopollenites liblarensis fallax		Arct.	Mix. Mesp.		+										
Tricolpopollenites parmularius	Fagaceae								+	+		+			
Tricolpopollenites pudicus	Quercus														+
Tricolpopollenites retiformis	Salix sp.	Arct.	Rip.	+	+	+		+	+	+	+	+	+		+
Tricolporopollenites baculoferus	Unknown	x	x							+					
Tricolporopollenites cingulum				+	+			+	+	+	+	+	+	+	+
Tricolporopollenites cingulum oviformis	Castanea sp.				+		+								
Tricolporopollenites cingulum fusus					+		+								
Tricolporopollenites cingulum pusillus		Arct.	Mix. Mesp.		+		+								
Tricolporopollenites dolium	Unknown	x	x						+		+		+		
Tricolporopollenites edmundi	Maxtixiaceae	Arct.	Mix. Mesp.		+					+					
Tricolporopollenites euphorii	Araliaceae	Comp.	Mesp.							+	+				
Tricolporopollenites genuinus	Unknown	x	x						+						
Tricolporopollenites helmsteddensis	Unknown								+	+					+
Tricolporopollenites kruschi	Nyssa	Ptr.	Swamp	+			+		+	+	+	+	+	+	+
Tricolporopollenites megaexactus exactus	Cyrillaceae			+	+	+	+	+	+	+	+	+	+		+
Tricolporopollenites megaexactus brühlensis		Ptr. or Str.	Mix. Meph.		+		+								
Tricolporopollenites microreticulatus		Ptr. or Str.	Mix. Mesp.	+	+	+	+	+	+	+	+	+	+		+
Tricolporopollenites margaritatus				+											
Tricolporopollenites iliacus	Oleaceae						+								

Tricolporopollenites microiliacus							+								
Tricolporopollenites pacatus	Simaraubaceae	Ptr. or Str.	Rip.		+	+			+	+	+	+	+		+
Tricolporopollenites porasper	Fagaceae	Arct.	Mix. Mesp.			+			+	+		+			
Tricolporopollenites villensis	Fagaceae				+	+				+			+		
Tricolporopollenites pseudocingulum	Anacardiaceae	Arct.	Mix. Mesp.		+				+	+	+	+	+		+
Tricolporopollenites satzveyensis	Unknown	x	x									+			
Tricolporopollenites sp.	Unknown				+		+		+			+			
Tricolporopollenites sp. *(Liguliflorae)*	Compositae	Comp	Herb.								+		+		+
Tricolporopollenites sp. *(Tubuliflorae)*											+		+		+
Tricolporopollenites steinensis	Unknown	x	x						+	+		+			+
Umbelliferaepollenites sp.	Umbelliferae	Comp.	Herb.										+		+
Undulatisporites concavus	Unknown	x	x	+											
Triporopollenites coryloides	Betulaceae	Arct.	Mix. Mesp.						+				+		+
Triporopollenites labraferus							+		+	+	+	+	+		+
Triporopollenites megagranifer	Juglandaceae									+			+	+	+
Triporopollenites simpliformis							+	+	+	+	+	+	+		+
Verrucatosporites favus										+					
Verrucatosporites scutulum	Unknown	x	x	+							+		+		
Verrucatosporites sp.				+		+	+							+	+
Pediastrum		Comp.	Fresh waterenvironment										+		
Dinoflagelate cysts		Comp.	Brachish environment	+	+										

Appendix B. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.palaeo.2007.03.034.

Appendix C
Species list of the megaflora from the Soma basin (Nebert, 1978; Gemici et al., 1991). The taxa used for the climatic analysis are marked in boldface type

***Acer* sp.**	***Myrica pseudolignitum* Kr. and Weyl in Mad. and Steff.**
***Acer trilobatum* (Stbg.) A.Br.**	***Myrica* sp.**
***Acer cf. decipens* (A. Br.) Heer**	*Nerium* sp.
***Apocynophyllum cf. helveticum* Heer**	***Olea* sp.**
Apocynophyllum sp.	*Percea* cf. *indica* Spreng in Kasap.
***Betula cf. prisca* Ett.**	*Phragnites* cf. *oeningensis* A. Br.
***Betula* sp.**	***Pinus palaeostrobus* (Ett.) Heer**
***Buxus sempervirens* L.**	*Pinus* cf. *pinaster* L.
***Buxus* sp.**	*Pinus* cf. *taeda* L.
***cf. Carpinus miocenica* Tan.**	*Pinus* sp.
Carya cf. *minor* Sap. and Mar.	***Pistacia lentiscus*** L.
***Carya* cf. *serraefolia* (Goepp.) Krä.**	*Planera ungeri* Heer
***Carya* sp.**	*Planera* sp.
***Castanea* cf. *sativa* Mill.**	cf. *Platanus aceroides* Goepp.
Castanea atavia Ung.	**cf. *Podogonium knorrii* Heer**
Castanea sp.	*Podogonium* sp.
Castanopsis furcinervis (Rossm.) Kr. and Weyl. (Mad. and Steff.)	***Populus mutabilis* Heer**
Ceratonia emarginata Heer	***Populus latior* A.Br.**
Ceratonia sp.	***Populus* cf. *balsamoides* Goepp.**
Cercis sp.	*Populus* sp.
Cinnamomum polymorphum Heer	***Quercus ilex* L.**
Cinnamomum scheuchzeri Heer	***Quercus oligodonta* Sap.**
Cinnamomum sp.	***Quercus drymeja* Ung.**
Clematis cf. *vitalba* L.	***Quercus kubinyii* (Kov.) Czec.**
Colutea salteri Heer	***Quercus mediterranea*** Unger
***Cornus* sp.**	***Quercus* cf. *aspera* Ung.**
Corylites sp.	***Quercus* cf. *buchi* Heer**
***Corylus* cf. *avellana* L.**	***Quercus* cf. *infectoria* Ol. in Dav.**
Dryophyllum sp.	***Quercus* cf. *neriifolia* A.Br.**
cf. *Equisetum* sp.	***Quercus* cf. *trojana* P. B. We. in Dav.**
Eucalyptus sp.	*Quercus* sp.
***Fagus ferruginea* Ait.**	*Robinia regeli* Heer
Fagus feroniae Ung.	*Robinia* sp.
***Fagus* sp.**	*Sagittaria* cf. *victor–masoni* Ward.
***Ficus lanceolata* Heer**	*Salicites* sp.

Appendix C (*continued*)

Ficus cf. *archinervis* Heer	*Salix angusta* Heer
Ficus cf. *tiliaefolia* Heer	*Salix longa* A.Br. (Mad. and Steff.)
Ficus sp.	*Salix varians* Goepp.
cf. *Frangula almus* Mill.	*Salix* sp.
Fraxinus excelsifolia Web. (Mad. and Steff.)	***Sapindus* cf. *falcifolia* A.Br.**
Glyptostrobus europaeus (Ett.) Heer	*Sequoia lansdorfii* (Br.) Heer
Glyptostrobus sp.	*Sideroxylon salicites* (Web) Wld.
cf. *Illicium chenanum* Kr. and Weyl. in Mad. and Steff.	*Sideroxylon* sp.
***Ilex* sp.**	***Taxodium distichum* Rich.**
Junlans acuminata A.Br.	***Taxodium dubium* (Stbg.) Heer**
Juncus sp.	***Taxodium* sp.**
***Laurophyllum primigenium* (Ung.) Kr. and Weyl. in Mad. and Steff.**	***Tilia* sp.**
***Laurophyllum princeps* (Heer) Kr. and Weyl**	cf. *Thuja occidentalis* L.
***Laurophyllum* sp.**	***Ulmus carpinoides* Goepp.**
***Magnolia* sp.**	cf. *Ulmus longifolia* Ung.
Magnolia ludwigi Ett.	*Ulmus* sp.
Morus cf. *rubra* L.	***Zelkova ungeri* Kov.**
***Myrica lignitum* (Ung.) Sap.**	***Ziziphus ziziphoides* (Ung) Weyl.**
***Myrica lignitum* (Ung.) Sap.**	***Ziziphus ziziphoides* (Ung) Weyl.**

References

Akgün, F., 1993. Palynological age revision of the Neogene Soma Coal Basin. Bulletin of the Geolological Society of Greece XXVIII/3, 151–170.

Akgün, F., Akyol, E., 1987. Akhisar (Çitak) çevresi kömürlerinin palinolojik incelemesi. Bulletin of the Geological Society of Turkey 30, 35–50 (in Turkish, English Abstr.).

Akgün, F., Akyol, E., 1999. Palynostratigraphy of the coal–bearing Neogene deposits graben in Büyük Menderes Western Anatolia. Geobios 32 (3), 367–383.

Akgün, F., Sözbilir, H., 2001. A Palynostratigraphic approach to the SW Anatolian Molasse Basin: Kale–Tavas and Denizli Molasse. Geodinamica Acta 14, 71–93.

Akgün, F., Ali°an, C., Akyol, E., 1986. Soma Neojen stratigrafisine palinolojik bir yaklaşım. Bulletin of the Geological Society of Turkey 29, 13–25 (in Turkish, English Abstr.).

Akgün, F., Olgun, E., Kuşçu, İ., Toprak, V., Göncüoğlu, M.C., 1995. Orta Anadolu kristalen kompleksinin "Oligo–Miyosen" örtüsünün stratigrafisi, çökelme ortamı ve gerçek yaşına ilişkin yeni bulgular. Turkish Association of Petroleum Geologists Bulletin 6 (1), 51–68 (in Turkish, English Abstr.).

Akgün, F., Kaya, T., Forsten, A., Atalay, Z., 2000. Biostratigraphic data (Mammalia and Palynology) from the Upper Miocene İncesu Formation at Düzyayla (Hafik Sivas, Central Anataloia). Turkish Journal of Earth Sciences 9, 57–67.

Akgün, F., Akay, E., Erdoğan, B., 2002. Terrestrial to shallow marine deposition in Central Anatolia: a palynological approach. Turkish Journal of Earth Sciences 11, 1–27.

Akgün, F., Kayseri, M.S, Akkiraz, M.S., 2004. Palaeoclimatic evolution and vegetational changes from the Oligocene to Miocene in Turkey. Neclime Annual Meeting, p. 7.

Akyol, E., Akgün, F., 1990. Bigadiç, Kestelek, Emet ve Kirka boratlı Neojen tortullarının palinolojisi ve karşılaştırılması. Maden Tetkik ve Arama Dergisi 11, 165–173.

Atalay, Z., 1980. Muğla–Yatağan ve yakın dolayı karasal Neojen'inin stratigrafi araştırması. Bulletin of the Geological Society of Turkey 23, 93–99 (in Turkish, English abstr.).

Bruijn, H., Saraç, G., 1991. Early Miocene rodent faunas from the eastern Mediterranean area Part I. The genus *Eumyarion*. Proceedings Koninklijke Academie van Wetenschappen 94 (1), 1–36.

Bruijn, H., Saraç, G., 1992. Early Miocene rodent faunas from the eastern Mediterranean area Part II. *Mirabella* (*Paracricetodontinea*, *Muroidea*). Proceedings Koninklijke Academie van Wetenschappen, Series B 95 (1), 25–40.

Bruch, A.A., Gabrielyan, I.G., 2001. Quantitative data of the Neogene climatic development in Armenia and Nakhichevan. Acta Universitatis Carolinae 46 (4), 27–38.

Cater, J.M.L., Hanna, S.S., Ries, A.C., Turner, P., 1991. Tertiary evolution of the Sivas Basin. Central Turkey. Tectonophysics 195, 29–46.

Çağlar, A.T., Ayhan, A., 1991. Geological features of the Haremikoy Ilgin–Konya region and lignite deposits. Journal of Engineering and Architecture, Faculty of Selcuk University 2, 20–35 (in Turkish, English Abstr.).

Erdei, B., Yavuz, N., Akgün, F., Hably, L., 2002. Some data to the Miocene flora of Western Turkey. 6th European Palaebotany Palynology Conference Athens, pp. 79–80.

Erdoğan, B., Akay, E., Ugur, M.S., 1996. Geology of the Yozgat region and evolution of the collisional Çankırı Basin. International Geology Review 38, 788–806.

Erol, O., 1981. Neotectonic and geomorphological evolution of Turkey. Zeitschrift für Geomorphologie, Neue Folge, Supplement Band 40, 193–211.

Gemici, Y., Akyol, E., Akgün, F., Seçmen, Ö., 1991. Soma kömür havzası fosil makro ve mikroflorası. Maden Tetkik ve Arama Dergisi 11, 161–178.

Görür, N., Tüysüz, O., 2001. Cretaceous to Miocene palaeogeographic evolution of Turkey: implications for hydrocarbon potential. Journal of Petroleum Geology 24 (2), 1–28.

Görür, N., Şengör, A.M.C., Sakınç, M., Tüysüz, O., Akkok, R., Yiğitbaş, E., Oktay, F.Y., Barka, A., Sarıca, N., Ecevitoğlu, B., Demirbağ, E., Ersoy, S., Algan, O., Güneysu, C., Aykol, A., 1995. Rift formation in the Gökova region, southwest Anatolia: implications for the opening of the Aegean Sea. Geological Magazine 132 (6), 637–650.

Gökçen, N., 1982. Denizli ve Muğla çevresi Neojen isti?nin Ostrakod biyostratigra?si. Yerbilimleri 9, 111–131.

Gürer, Ö.F., Yılmaz, y., 2002. Geology of the Ören and surrounding areas, SW Anatolia. Turkish Journal of Earth Sciences 11, 1–13.

Hakyemez, Y.H., 1989. Geology and stratigraphy of the Cenozoic sedimentary rocks in the Kale–Kurbalık area. Denizli–southwestern Turkey. Bulletin of the Mineral Research Exploration 109, 9–21.

Hakyemez, H.Y., Örçen, S., 1982. Muğla Denizli arasındaki (GB Anadolu) Senozoyik yaşlı çökel kayaların sedimentolojik ve biyostratigra?k incelenmesi. Mineral Research Exploration Institute 7311.

Helvacı, C., 1995. Stratigraphy, mineralogy and genesis of the Bigadiç borate deposits, Western Turkey. Economic Geology 90, 1237–1260.

Helvacı, C., Mordoğan, H., Çolak, M., Gündoğan, İ., 2004. Presence and distribution of lithium in borate deposits and some recent lake waters of West–Central Turkey. International Geology Review 46, 177–190.

Hochuli, P.A., 1978. Palynologische untersuchungen im Oligozän und Untermiozän der Zentralen und Weslichen Paratethys. Beitrräge Paläontologie Österreich 4, 1–132.

İnci, U., 1998. Miocene synvolcanic alluvial sedimentation in lignite bearing Soma Basin, western Turkey. Turkish Journal of Earth Sciences 7, 63–78.

İnci, U., 2002. Depositional evolution of Miocene coal successions in the Soma coalfield, western Turkey. International Journal of Coal Geology 51, 1–29.

Ivanov, D., Ashraf, A.R., Mosburugger, V., Palamarev, E., 2002. Palynological evidence for Miocene climate change in the Forecarpathian Basin (Central Paratethys, NW Bulgaria). Palaeogeography, Palaeoclimatology, Palaeoecology 178, 19–37.

Karayiğit, A.İ., Akgün, F., Gayer, R.A., Temel, A., 1999. Quality, palynology, and palaeoenvironmental interpretation of the Ilgin lignite, Turkey. International Journal of Coal Geology 38, 219–236.

Kayseri, M.S., 2002. Palynostratigraphic correlation of the Miocene sediments with lignites and their depositional environments in the Central Anatolia, Turkey. MS.c. Thesis Dokuz Eylül Univ. İzmir, Turkey.

Kaymakçı, N., Özçelik, Y., White, H.S., Van Dijk, P.M., 2001. Neogene tectonic development of the Çankırı basin (Central Anatolia, Türkiye). Turkish Association of Petroleum Geologists Bulletin 13 (1), 27–56.

Kayseri, M.S., Akgün, F., 2002. Palynostratigraphic correlation of the Miocene sediments with lignites and their depositional environments in the Central Anatolia, Turkey. 6th European Palaebotany–Palynology Conference Greece, pp. 217–218.

Kirchner, M., 1984. Die Oberoligozäne mikroflora des südbayerischen pechkohlenreviers. Paleontographica Abteilung B Ionnides 192, 85–162.

Koçyiğit, A., 1984. Güneybatı Türkiye ve yakın dolayında levhaiçi yeni tektonik gelişim. Bulletin of the Geological Society of Turkey 27, 1–16.

Koçyiğit, A., Türkmenoğlu, A., Beyhan, A., Kaymakçı, N., Akyol, E., 1995. Post-collisisonal tectonics Eskişehir–Ankara–Çankırı segment of İzmir–Ankara–Erzincan suture zone. Turkish Association of Petroleum Geologists Bulletin 6 (1), 69–87.

Kovach, W.L., 1988. Quantitative paleoecology of megaspores and other dispersed plant remains from Cenomanian of Kansas, USA. Cretaceous Research 9, 265–283.

Kovach, W.L., 1989. Comparisons of multivariate analytical techniques for the use in pre Quaternary plant paleoecology. Review of Palaeobotany and Palynology 60, 255–282.

Langereis, C.G., Şen, S., Sümengen, M., Ünay, E., 1990. Preliminary magnetostratigraphic results of some Neogene mammal localities from Anatolia (Turkey). Europen Neogene Mammal Chronology, NATO ASI, Series A, pp. 515–525.

Liang, M.M., Bruch, A., Collinson, M., Mosbrugger, V., Li, C.S., Sun, Q.G., Hilton, J., 2003. Testing the climatic estimates from different palaeobotanical methods: an example from the Middle Miocene Shanwang flora of China. Palaeogeography, Palaeoclimatology, Palaeoecology 198, 279–301.

Luttig, G., Steffens, P., 1976. Explanatory notes for the palaeogeographic atlas of Turkey from the Oligocene to the Pleistocene. Bundesansalt für Geowissenchaften und Rohstoffe Hannover 64.

Mai, D.H., 1991. Palaeofloristic changes in Europe and the confirmation of the Arctotertiary-Palaeotropical geofloral concept. Review of Palaeobotany and Palynology 68, 29–36.

Mosbrugger, V., 1995. New methods and approaches in Tertiary palaeoenvironmental research. Abhandlungen des Staatlichen Museums für Minerologie und Geologie zu Dresden 41, 41–52.

Mosbrugger, V., Utescher, T., 1997. The coexistence approach–a method for quantitative reconstructions of Tertiary terrestrial paleoclimate data using the plant fossils Palaeogeography. Palaeogeography, Palaeoclimatology, Palaeoecology 134, 61–86.

Mosbrugger, V., Utescher, T., Dilcher, D.L., 2005. Cenozoic continental climatic evolution of Central Europe. Proceedings of the National Academy of Sciences of the United States of America (PNAS) 102 (42).

Nagy, E., 1990. Palynological correlation of the Neogene of the Central Paratethys. Geological Institute of Hungary 1–126.

Nebert, K., 1961. Gördes bölgesindeki Neojen volkanizması hakkında bilgiler. Maden Tetkik ve Arama Dergisi 57, 50–54.

Nebert, K., 1978. Linyit içeren Soma Neojen bölgesi, Batı Anadolu. Maden Tetkik ve Arama Dergisi 90, 20–60.

Özdemir, İ., 2000. Gemerek (Sivas) çevresinin linyit havza etüdü. Maden Tetkik Arama Enstitüsü Raporu 91–42a, 1–50.

Planderová, E., 1991. Miocene microflora of Slovak Central Paratethys and its biostratigraphical significance. Vydal Geologickı ústav Dioıza Štura, Roku 1–144.

Poisson, A., Guezou, J.C., Öztürk, A., İnan, S., Temiz, H., Gürsoy, H., Kavak, K.S., Özden, S., 1996. Tectonic setting and evolution of the Sivas Basin, Central Anatolia, Turkey. International Geology Review 38, 838–853.

Pross, J., Bruch, A.A., Mosbrugger, V., Kvacek, Z., 2001. Paleogene pollen and spores as a tool for quantitative paleoclimate reconstructions. In: Goodman, D.K., Clarke, R.T. (Eds.), The Rupelian (Oligocene) of Central Europe. . Proceedings of the IX International Palynological Congress, Houston, Texas, USA., 1996. American Association of Stratigraphic Palynologists Foundation, pp. 299–310.

Seyitoğlu, G., Scott, B., 1991. Late Cenozoic crustal extension and basin formation in west Turkey. Geological Magazine 128, 155–166.

Seyitoğlu, G., Scott, B.C., 1994. Late Cenozoic basin development in west Turkey: Gördes basin: tectonics and sedimentation. Geological Magazine 5 (131), 631–637.

Spicer, R.A., Hill, C.R., 1979. Principal components and correspondence analyses of quantitative data from a Jurassic plant bed. Review of Palaeobotany and Palynology 28, 273–299.

Sümengen, M., Ünay, E., Saraç, G., Bruijn, Hans, Terlemez, I., Gürbüz, M., 1990. New Neogene rodent assemblages from Anatolia (Turkey). Bulletin of the Geological Society of Turkey 62–72.

Syabryaj, S., 2002. Vegetation and climate of the Ukraine in the Neogene. Acta Universitatis Carolinae 46 (4), 49–56.

Şen, Ş., Seyitoğlu, G., Karadenizli, L., Kazanci, N., Varol, B., Araz, H., 1998. Mammalian Biochronology of Neogene Deposits and its Correlation with the Lithostratigraphy in the Çankırı–Çorum Basin, Central Anatolia, Turkey. Eclogae Geologica Helvetiae 91, 307–320.

Şengör, A.M.C., Yılmaz, Y., 1981. Tethyan evolution of Turkey: A plate tectonic approach. Tectonophysics 75, 181–241.

Şengör, A.M.C., Görür, N., Şaroğlu, F., 1985. Strike–slip faulting and related basin formation in zones of tectonic escape. In: Biddle, K.T., Chiristte–Blick, N. (Eds.), Strike–slip deformation and sedimentation. Society of Economic Paleontologists and Mineralogist, Special Publications, vol. 37, pp. 227–264.

Takahashi, E., Jux, U., 1991. Miocene palynomorphs from lignites of the Soma Basin. Bull. Faculty of Liberal Arts, Nagasaki University. Natural Science 31 (1), 7–165.

Tunoglu, C., Celik, M., 1995. The ostracoda association and environmental characteristics of Lower Miocene sequence of Ilgin Konya district, Central Anatolia, Turkey. In: Riha, J. (Ed.), Ostracoda and Biostratigraphy. Balkema, Rotterdam, pp. 229–235.

Utescher, T., Mosbrugger, V., Ashraf, A.R., 2000. Terresterial Climate Evolution in Northwest Germany over the Last 25 Million Years. Palaios 15, 430–449.

Yağmurlu, F., 1984. Stratigraphy depositional environments and tectonic features of Miocene coal–bearing sediments east of Akhisar, west Turkey. Bulletin of the Geological Congress of Turkey 5, 3–20.

Yağmurlu, F., Helvacı, C., ve Inci, U., 1988. Depositional setting and geometric structure of Beypazarı lignite deposits, Central Anatolia. International Journal of Coal Geology 10, 337–360.

Yılmaz, A., 1983. Tokat (Dumanlıdağ) ile Sivas (Çeltekdağ›) dolaylarının temel jeolojik özellikleri ve ofiyolitli karışığın konumu. Mineral Research and Exploration Institute of Turkey Bulletin 99, 1–18 (in Turkish, English abstr.).

Yılmaz, Y., 1992. New evidence and model on the evolution of the southeastern Turkey. American Association of Petroleum Geologist Bulletin 105, 251–271.

Yılmaz, Y., 1994. Çarpışma sonrası bir çanak örneği: Sivas Havzası, Türkiye. Proceedings of 9th Turkish Petroleum Congress Turkey, Ankara. Turkish Association of Petroleum Geologists, pp. 21–32.

Yılmaz, Y., Tüysüz, O., Yiğitbaş, E., Genç, Ş.C., Şengör, A.M.C., 1997. Geology and tectonic evolution of Pontides. In: Robinson, A.G. (Ed.), Regional and Petroleum Geology of the Black Sea and Surrounding Region, vol. 68. American Association of Petroleum Geologists, pp. 183–226.

Yılmaz, Y., Genç, Ş.C., Gürer, F., Bozcu, M., Yılmaz, K., Karaycık, Z., Altunkaynak, Ş., Elmas, A., 2000. When did the western Anatolian grabens begin to develop? In: Bozkurt, E., Winchester, J.A., Piper, J.D.A. (Eds.), Tectonics and Magmatism in Turkey and Surrounding Area. Geological Society Special Pubication, vol. 173, pp. 353–384.

Zachos, J., Pagani, M., Sloan, L., Thomas, E., Billups, K., 2001. Trends, rhythms, and aberrations in Global Climate 65 Ma to present. Science 292, 686–693.

All climate data provided here are accessible by the world data base PANGAEA under the reference

Akgün, F., Kayseri, M.S., Akkiraz, M.S., 2007. Neogene palaeoclimate reconstrucitions in Anatolia (Turkey). PANGAEA. doi:10.1594/PANGAEA.596351.